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AN ANALYSIS OF TRANSMITTANCES MEASURED THROUGH BATTLEFIELD DUST CLOUDS

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Measurements of transmittance through dust and debris clouds generated by explosions and moving vehicles were analyzed to determine if transmittance is better for one wavelength than some other. Statistical tests were performed to determine whether the amounts of time that transmittance was reduced to specified levels were significantly different for various wavelengths. In certain types of cases, differences were detected with the 8μm to 12μm wavelengths shown to be better than the others measured. In other cases, no significant differences were found; thus, transmittance was wavelength independent.

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CONTENTS

INTRODUCTION

Whether operation at one specific wavelength is significantly better than at some other is a question of major importance within the Army to developers and users of weapon systems and sensors which employ electro-optical devices. Airborne soil particles can seriously degrade the transmission of electromagnetic energy through the atmosphere for radiation at lasers wavelengths. Calculations made by Patterson[1] show that extinction due to soil-derived aerosols is approximately wavelength independent between 0.55μm and 10.6μm for a range of measured and model particle size distributions.

However, the conclusions reached by Patterson may not be valid for aerosols induced by battlefield activities such as dust and debris clouds generated by explosions or vehicular activities. In an effort to determine whether transmittance is better at one wavelength than another for battlefield conditions, a study was conducted by using transmittance measurements taken during several field tests.

Transmittance measurements at several wavelengths were made through dust and debris clouds generated by munitions, explosives, and moving vehicles under a variety of conditions. The data obtained were processed to determine the amount of time during each trial the measured transmittances were less than specified levels. Visual examination of these processed data showed that in many of the individual trials there were no major differences between the various wavelengths in the amount of time that transmittance was reduced. In other trials, differences between wavelengths were apparent. To have a scientific basis for such conclusions, statistical tests were applied to the resulting information to determine whether the transmittance at any one wavelength was significantly different from the others.

SOURCES OF DATA

Transmittance measurement data used in this study were obtained during four field tests:

1. Dust and Debris Test[2] conducted at Fort Sill, Oklahoma, May 1978;

2. Dust Trial Phase of Smoke Week I[3] conducted at Dugway Proving Ground, Utah, November-December 1977;

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[1]E. M. Patterson, 1977, "Atmospheric Extinction between 0.55μm and 1.06μm Due to Soil-Derived Aerosols," Applied Optics, 16:2414-2418

[2]US Army Dugway Proving Ground, 1978, "Dust/Debris Test Conducted at Fort Sill, Oklahoma, by Dugway Proving Ground," DPG-FR-78-313, Dugway, UT

[3]US Army Dugway Proving Ground, 1977, "Dust Trial Phase of Inventory Smoke Munition Test (Phase IIa)," DPG-FR-77-317, Dugway, UT

3. Smoke Week II[4] conducted at Eglin AFB, Florida, November 1978; and

4. Dusty Infrared Test I (DIRT-I)[5,*] conducted at White Sands Missile Range, New Mexico, October 1978.

Measurements for the Fort Sill test and both Smoke Week tests were made with telephotometers and transmissometers from Dugway Proving Ground. Measurements were made at 9.75μm, 3.443μm, 1.06μm, and 0.4μm to 0.7μm (referred to as "visible" later) in each test. The Naval Research Laboratory made measurements during DIRT-I at 10.35μm, 1.06μm, and 0.55μm, but the 1.06μm data were not considered reliable and were not used in this analysis. Length of the line-of-sight was 1106 m during the Fort Sill test, 600 m during Smoke Week I, 800 m during Smoke Week II, and 2 km during DIRT-I.

Individual trial numbers, sources of dust clouds, and duration of the data used in this analysis are summarized in table 1. Additional information concerning these tests and the individual trials may be found in the references.

METHODS USED TO PROCESS DATA

When examining the transmittance versus time data, one has difficulty determining if the transmittance at one wavelength is significantly "better" than at another. Figures 1 and 2 are plots of the transmittance measurements taken during one of the trials of the Fort Sill Dust and Debris Test which show the difficulty of such analysis. To obtain information more readily analysed, the durations of time for which the measured transmittance was less than specified levels were computed. Then the percentage of the time the transmittance was below each level was found for each wavelength and each trial. Plots of this information are given in figures 3 through 59, where K is the specified level that the transmittance did not exceed. The total amount of time for which data was processed varied for the individual trials but was as nearly the same as practical for all wavelengths in each trial.

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[4]US Army Dugway Proving Ground, 1979, "Smoke Week II Test Final Report," Volume 2, DPG-FR-78-317, Dugway, UT

[5]J. D. Lindberg, ed., 1979, "Measured Effects of Battlefield Dust and Smoke on Visible, Infrared, and Millimeter Wavelength Propagation: A Preliminary Report on Dusty Infrared Test-I (DIRT-I)," ASL-TR-0021, Atmospheric Sciences Laboratory, White Sands Missile Range, NM

*Naval Research Laboratory, 1979, unpublished transmissometer data from DIRT-I, Washington, DC

TABLE 1. TEST DATA USED IN ANALYSIS

Test Series	Trial	Dust Source	Duration of Data (s)
Fort Sill Test (ref 2)	P1	Vehicle	104
	P2	Vehicle	130
	P3	Vehicle	123
	P4	Vehicle	50
	03	155 mm 1 round	58
	04	155 mm 3 rounds	58
	05	155 mm 3 rounds	51
	06	155 mm 3 rounds	59
	07	155 mm 3 rounds	47
	08	155 mm 3 rounds	89
	09	155 mm 2 rounds	57
	10	155 mm 2 rounds	74
	11	155 mm 2 rounds	36
	12	105 mm 1 round	58
	13	105 mm 1 round	40
	14	105 mm 1 round	58
	15	105 mm 1 round	49
	16	105 mm 1 round	73
	17	105 mm 1 round	73
	18	105 mm 1 round	59
	19	105 mm 1 round	73
	20	105 mm 1 round	59
	21	105 mm 4 rounds	88
	22	105 mm 5 rounds	72
Smoke Week I (ref 3)	D1	TNT 3.5 lb	99
	D2	TNT 5 lb	99
	D3	TNT 8 lb	99
	D4	TNT 6.75 lb	99
	D5	TNT 13 lb	99
	D6R	TNT 35 lb	99
Smoke Week II (ref 4)	23	105 mm 6 rounds	117
	23R	105 mm 6 rounds	113
	26	155 mm 6 rounds	120
	27	Vehicle	119
	29	155 mm 6 rounds	117
	30	105 mm 6 rounds	137
DIRT I (ref 5 and unpublished Naval Research Lab data from DIRT-I)	B1	TNT three 15-lb charges	358
	B2	TNT three 15-lb charges	238
	B3	TNT three 30-lb charges	299
	B4	TNT three 30-lb charges	300
	B5	TNT three 60-lb charges	360
	B6	TNT three 60-lb charges	420
	B7	TNT three 120-lb charges	597
	B8	TNT three 120-lb charges	1014
	C1	TNT one hundred and forty 15-lb charges	840
	E1	155 mm 3 rounds	360
	E2	155 mm 3 rounds	360
	E3	155 mm 12 rounds	300
	E4	155 mm 12 rounds	360
	F1	155 mm 4 rounds	180
	F2	155 mm 12 rounds	420
	F3	155 mm 12 rounds	300
	F4	155 mm 8 rounds	480
	F5	155 mm 8 rounds	480
	F6	155 mm 8 rounds	240
	F7	155 mm 8 rounds	360
	F8	155 mm 3 rounds	230

Examination of these plots shows that for some trials there is very little variation by wavelength, while for others the variation is relatively large.

RESULTS OF STATISTICAL TESTS FOR INDIVIDUAL TRIALS

The data illustrated in figures 3 through 59 were analyzed to determine if any significant differences could be detected among the various wavelengths for each individual trial. The Kolmogorov-Smirnov test[6] was used for each pair of wavelengths to determine if the data sets were from the same or different distributions. This test is usually used to compare cumulative probability distributions. In this case, it was assumed that the computed percentages of time that transmittance was below specified levels are equivalent to cumulative probability distributions and that the Kolmogorov-Smirnov test may be used to test two sample distributions when the underlying distribution is not known. A level of significance of 0.05 was used, meaning that there is a 5 percent chance of finding that the two data sets are not from the same distribution when they actually are. The test statistic computed is the absolute maximum difference for two wavelengths between the percentages of time transmittance was reduced for the set of specified transmittance levels. If this maximum is greater than the Kolmogorov-Smirnov test statistic for that sample size (assumed equal to total number of seconds), then a significant difference has been found. Results of these tests are shown in table 2, in which S indicates that the two data sets are found to be from the same distribution, X indicates that the two data sets are not from the same distribution, and a dash (-) indicates that the data were not available.

Several conclusions may be drawn from the results of these tests.

1. There was no significant difference detected between the 3.443μm and 1.06μm transmission for any test.

2. The 9.75μm and the visible transmission were found to be significantly different most frequently.

3. Significant differences were less frequently detected for trials consisting of single explosions than for the multiple round tests and vehicular dust tests.

4. In most of the DIRT-I trials in which significant differences were detected, the 0.55μm wavelength was better than the 10.35μm wavelength. (See trials B8, C1, E1, E2, F2, F3.) This finding is contrary to what was expected.

However, we did not find that one wavelength was "better" than another most of the time.

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[6] H. M. Walker and J. Lev, 1953, Statistical Inference, Henry Holt and Company, New York

TABLE [illegible]. KOLMOGOROV-SMIRNOV STATISTICAL TEST RESULTS

Test Series	Trial	9.75- Visible	3.443- Visible	1.06- Visible	9.75- 3.443	9.75- 1.06	3.443- 1.06	10.35- 0.55
Fort Sill Test	P1	X	X	S	S	S	S	-
	P2	S	S	S	S	X	S	-
	P3	S	S	S	X	X	S	-
	P4	X	S	S	S	X	S	-
	03	S	S	S	S	S	S	-
	04	S	S	S	S	S	S	-
	05	S	S	S	S	S	S	-
	06	S	S	S	S	S	S	-
	07	S	S	S	S	S	S	-
	08	S	S	S	S	S	S	-
	09	S	S	S	S	S	S	-
	10	X	X	S	S	S	S	-
	11	S	S	S	S	S	S	-
	12	S	S	S	S	S	S	-
	13	S	S	S	S	S	S	-
	14	S	S	S	S	S	S	-
	15	S	S	S	S	S	S	-
	16	S	S	S	S	S	S	-
	17	S	S	S	S	S	S	-
	18	S	S	S	S	S	S	-
	19	S	S	S	S	S	S	-
	20	S	S	S	S	S	S	-
	21	S	S	S	S	S	S	-
	22	S	-	S	-	S	-	-
Smoke Week I	D1	X	X	X	S	S	S	-
	D2	X	S	S	S	S	S	-
	D3	X	X	X	S	S	S	-
	D4	S	S	S	S	S	S	-
	D5	X	S	X	S	S	S	-
	D6R	X	X	X	S	S	S	-
Smoke Week II	23	S	S	S	S	S	S	-
	23R	S	S	S	S	S	S	-
	26	S	S	S	S	S	S	-
	27	S	S	S	S	S	S	-
	29	S	S	S	S	S	S	-
	30	S	S	S	S	S	S	-
DIRT-I	B1	-	-	-	-	-	-	S
	B2	-	-	-	-	-	-	S
	B3	-	-	-	-	-	-	S
	B4	-	-	-	-	-	-	S
	B5	-	-	-	-	-	-	S
	B6	-	-	-	-	-	-	S
	B7	-	-	-	-	-	-	S
	B8	-	-	-	-	-	-	X
	C1	-	-	-	-	-	-	X
	E1	-	-	-	-	-	-	X
	E2	-	-	-	-	-	-	X
	E3	-	-	-	-	-	-	S
	E4	-		-	-	-	-	S
	F1	-	-	-	-	-	-	S
	F2	-	-	-	-	-	-	X
	F3	-	-	-	-	-	-	X
	F4	-	-	-	-	-	-	S
	F5	-	-	-	-	-	-	X
	F6	-	-	-	-	-	-	S
	F7	-	-		-	-	-	X
	F8	-	-	-	-	-	-	S

RESULTS OF STATISTICAL TESTS FOR THE COMBINED DATA SET

While the results of the statistical tests done on individual trials yield interesting information, results from combinations of the data from several trials could be more important. In investigating this aspect, mean values of the fraction (percentage/100) of the time for which the transmission did not exceed the value of K were computed for each wavelength for several combinations of the individual trials. For example, mean values were computed for the five tests involving vehicular dust. Then, the mean values for each pair of wavelengths were tested for equality using the Student's t-test. This test is used for comparing the means of two normal populations when the standard deviations are not known and cannot be considered equal. Table 3 gives the results of these tests for the combined vehicular dust data, along with the means and standard deviations used in the statistical tests. A level of significance of 0.05 was used for a one-tailed test. The test statistic computed is

$$Z = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{S_1^2}{n} + \frac{S_2^2}{n}}}$$

where $\overline{X}_i$ is the mean value of the time the transmittance was reduced to the specified level for wavelength i, s_i is the standard deviation, and n is the number of cases. If Z is greater than the student t-statistic, then a significant difference has been found. In table 3, the symbol S indicates that no significant difference was found, while an X indicates that one mean is significantly larger than the other.

Likewise, table 4 gives the same information for the trials which involved single rounds of munitions or explosives for a total of 16 cases. Other combinations involving multiple round trials produced no significant differences in the mean values. Tables 5 through 7 give means and standard deviations for combined multiple round trials.

Conclusions which may be drawn from these tests are as follows:

1. At several important levels of transmission, between 0.3 and 0.8, the 9.75μm wavelength was significantly better than 3.443μm and 1.06μm in vehicular dust; that is, the obscuration to the lower levels of transmission had shorter duration at 9.75μm.

2. In vehicular dust, the 9.75μm wavelength was marginally better than the visible, but no other significant differences were detected.

3. In the case of dust and debris clouds generated by single explosions, the 9.75μm wavelength was significantly better than 3.443μm, 1.06μm, or visible.

TABLE 3. STATISTICAL TEST RESULTS FOR COMBINED VEHICULAR DUST DATA (5 CASES)

	Means				Standard Deviations				Test Results					
K	9.75	3.443	1.06	Visible	9.75	3.443	1.06	Visible	3.443–9.75	1.06–9.75	1.06–3.443	Visible 9.75	Visible 3.443	Visible 1.06
0.1	0.000	0.000	0.001	0.000	0.000	0.000	0.002	0.000	S	S	S	S	S	S
0.2	0.001	0.007	0.013	0.004	0.001	0.010	0.016	0.007	S	S	S	S	S	S
0.3	0.008	0.051	0.060	0.046	0.009	0.034	0.036	0.037	X	X	S	X	S	S
0.4	0.051	0.109	0.123	0.099	0.040	0.049	0.047	0.048	X	X	S	S	S	S
0.5	0.102	0.170	0.198	0.171	0.055	0.063	0.054	0.067	S	X	S	S	S	S
0.6	0.175	0.262	0.314	0.263	0.074	0.048	0.055	0.081	X	X	S	S	S	S
0.7	0.281	0.370	0.430	0.383	0.076	0.061	0.075	0.094	X	X	S	X	S	S
0.8	0.434	0.560	0.601	0.555	0.086	0.083	0.135	0.156	X	X	S	S	S	S
0.9	0.699	0.737	0.748	0.708	0.075	0.101	0.122	0.189	S	S	S	S	S	S

TABLE 4. STATISTICAL TEST RESULTS FOR COMBINED SINGLE FOUND DUST DATA (16 CASES)

	Means				Standard Deviations				Test Results					
P	9.75	3.443	1.06	Visible	9.75	3.443	1.06	Visible	3.443-9.75	1.06-9.75	1.06-3.443	Visible 9.75	Visible 3.443	Visible 1.06
0.1	0.026	0.039	0.064	0.061	0.032	0.037	0.044	0.031	S	X	X	X	X	S
0.2	0.050	0.081	0.102	0.105	0.037	0.036	0.044	0.038	X	X	S	X	X	S
0.3	0.082	0.111	0.126	0.131	0.032	0.033	0.046	0.043	X	X	S	X	S	S
0.4	0.111	0.134	0.148	0.153	0.030	0.038	0.046	0.044	X	X	S	X	S	S
0.5	0.131	0.159	0.175	0.178	0.036	0.041	0.051	0.053	X	X	S	X	S	S
0.6	0.155	0.180	0.191	0.199	0.039	0.047	0.055	0.067	S	X	S	X	S	S
0.7	0.180	0.211	0.223	0.225	0.048	0.057	0.066	0.077	S	X	S	S	S	S
0.8	0.223	0.249	0.259	0.291	0.064	0.069	0.075	0.167	S	S	S	S	S	S
0.9	0.288	0.305	0.317	0.336	0.079	0.093	0.091	0.213	S	S	S	S	S	S

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TABLE 5. STATISTICS FOR COMBINED MULTIPLE ROUND DUST DATA (14 CASES)

	Means				Standard Deviations			
K	9.75	3.443	1.06	Visible	9.75	3.443	1.06	Visible
0.1	0.215	0.254	0.275	0.282	0.111	0.130	0.133	0.132
0.2	0.272	0.301	0.321	0.324	0.132	0.129	0.137	0.137
0.3	0.310	0.331	0.350	0.350	0.124	0.129	0.131	0.133
0.4	0.338	0.362	0.378	0.377	0.124	0.131	0.126	0.129
0.5	0.370	0.398	0.422	0.422	0.125	0.124	0.126	0.129
0.6	0.408	0.435	0.452	0.456	0.127	0.122	0.127	0.128
0.7	0.448	0.469	0.487	0.488	0.124	0.126	0.141	0.140
0.8	0.488	0.501	0.521	0.536	0.134	0.136	0.137	0.142
0.9	0.567	0.583	0.602	0.624	0.151	0.155	0.159	0.156

TABLE 6. STATISTICS FOR TNT TRIALS OF DIRT-I (9 CASES)

	Means		Standard Deviations	
K	0.55	10.35	0.55	10.35
0.1	0.122	0.105	0.137	0.109
0.2	0.146	0.151	0.154	0.155
0.3	0.159	0.167	0.157	0.157
0.4	0.184	0.195	0.162	0.166
0.5	0.210	0.215	0.177	0.180
0.6	0.225	0.230	0.189	0.190
0.7	0.243	0.254	0.203	0.212
0.8	0.270	0.315	0.221	0.242
0.9	0.375	0.406	0.255	0.269

TABLE 7. STATISTICS FOR 155 mm TRIALS OF DIRT-I (12 CASES)

	Means		Standard Deviations	
K	0.55	10.35	0.55	10.35
0.1	0.212	0.171	0.140	0.136
0.2	0.228	0.207	0.141	0.127
0.3	0.247	0.243	0.144	0.134
0.4	0.270	0.269	0.155	0.134
0.5	0.292	0.312	0.172	0.148
0.6	0.323	0.362	0.183	0.184
0.7	0.361	0.410	0.209	0.231
0.8	0.387	0.460	0.234	0.231
0.9	0.418	0.515	0.275	0.233

4. Other significant differences for single rounds were detected only at very low transmission values (0.1 and 0.2) between 3.443μm and 1.06μm and between 3.443μm and visible, with the 3.443μm being the better.

5. No significant differences were found in the multiple rounds cases, including combinations of DIRT-I trials, probably because of the large variation in the test conditions among the individual trials, rather than the transmittance actually being wavelength independent.

SUMMARY

A set of transmittance data from 57 separate trials involving dust and debris clouds generated by explosives and vehicles was analyzed to determine if significant differences could be detected for the various wavelengths. In many of the individual cases, no differences could be detected in the amount of time that the transmittance was reduced to specified levels. In 28 percent of the cases, a significant difference was detected between the transmittance in the 8μm to 12μm region and the visible region. In no case was a difference detected between transmittance at 1.06μm and visible.

Analysis of combined data from the vehicular dust trials showed that transmittance at 9.75μm was better than at 3.443μm and 1.06μm. Transmittance at 9.75μm was better than at 3.443μm, 1.06μm, and visible for combined data from single explosion trials. Analysis of combined data from multiple round trials yielded no significant differences, but probably the variations in test conditions caused the results of the statistical tests to be indeterminate.

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1. Patterson, E. M., 1977, "Atmospheric Extinction between 0.55μm and 1.06μm Due to Soil-Derived Aerosols," Applied Optics, 16:2414-2418.

2. US Army Dugway Proving Ground, 1978, "Dust/Debris Test Conducted at Fort Sill, Oklahoma, by Dugway Proving Ground," DPG-FR-78-313, Dugway, UT.

3. US Army Dugway Proving Ground, 1977, "Dust Trial Phase of Inventory Smoke Munition Test (Phase IIa)," DPG-FR-77-317, Dugway, UT.

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5. Lindberg, J. D., ed., 1979, "Measured Effects of battlefield Dust and Smoke on Visible, Infrared, and Millimeter Wavelength Propagation: A Preliminary Report on Dusty Infrared Test - I (DIRT-I)," ASL-TR-0021, Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

6. Walker, H. M., and J. Lev, 1953, Statistical Inference, Henry Holt and Company, New York.

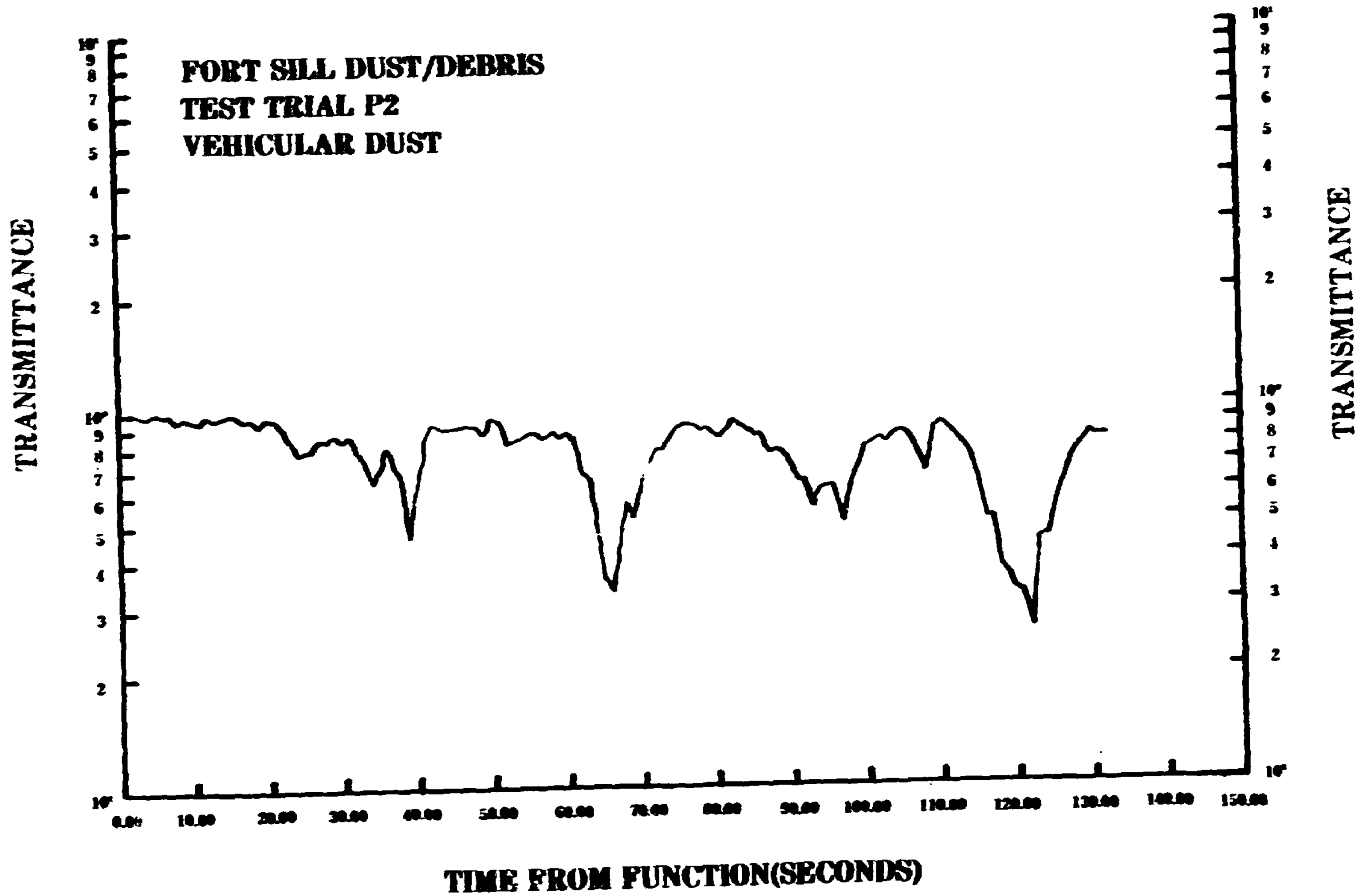

Figure 1. Transmittance versus time for wavelength 9.75μm (Ref 2).

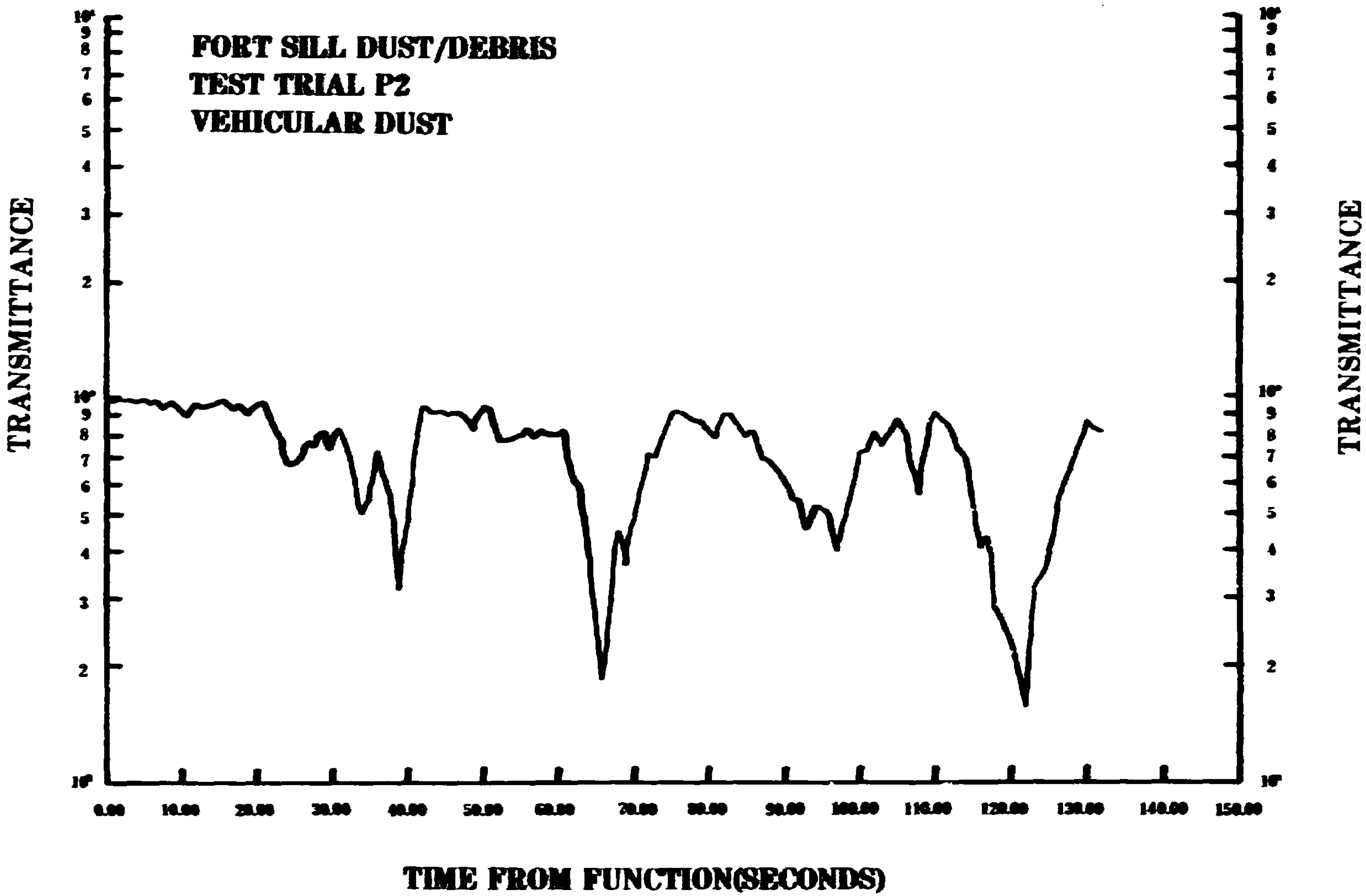

Figure 2. Transmittance versus time for wavelength 3.443μm (Ref 2).

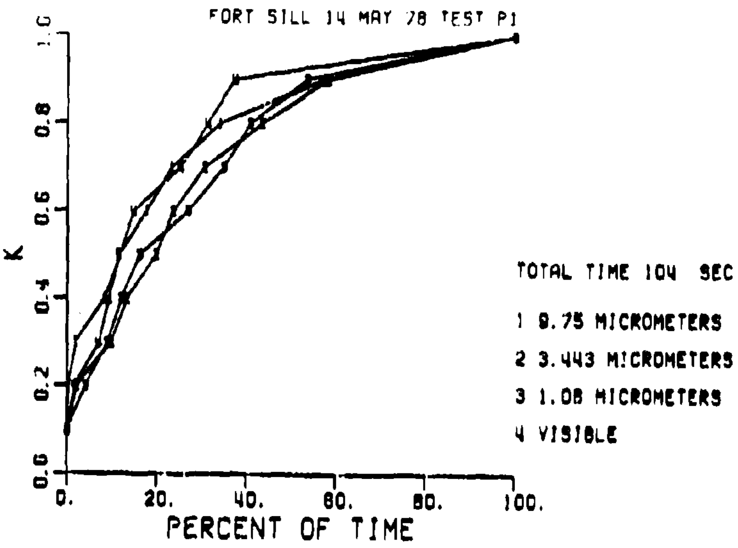

Figure 3. Percent of time measured transmittance was less than K, Fort Sill Test P1.

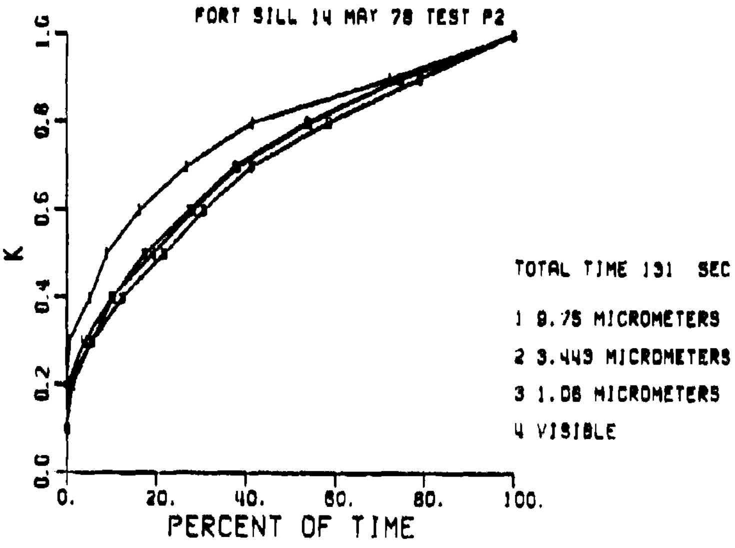

Figure 4. Percent of time measured transmittance was less than K, Fort Sill Test P2.

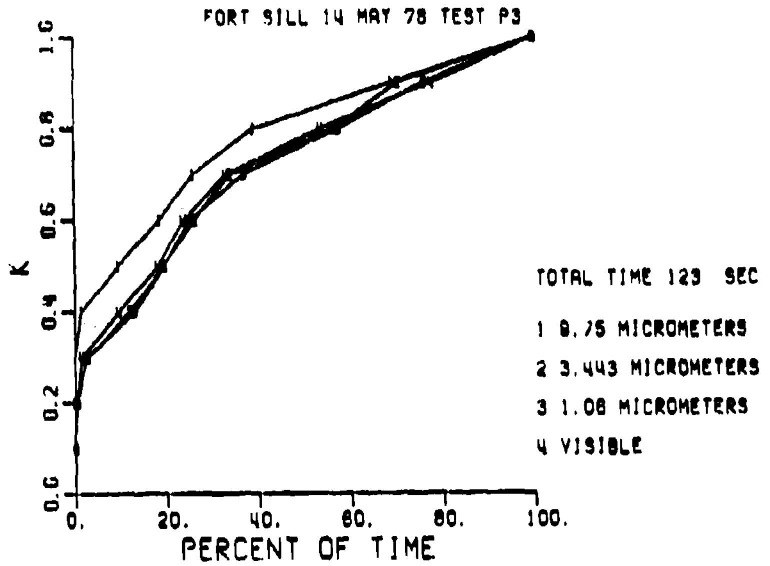

Figure 5. Percent of time measured transmittance was less than K, Fort Sill Test P3.

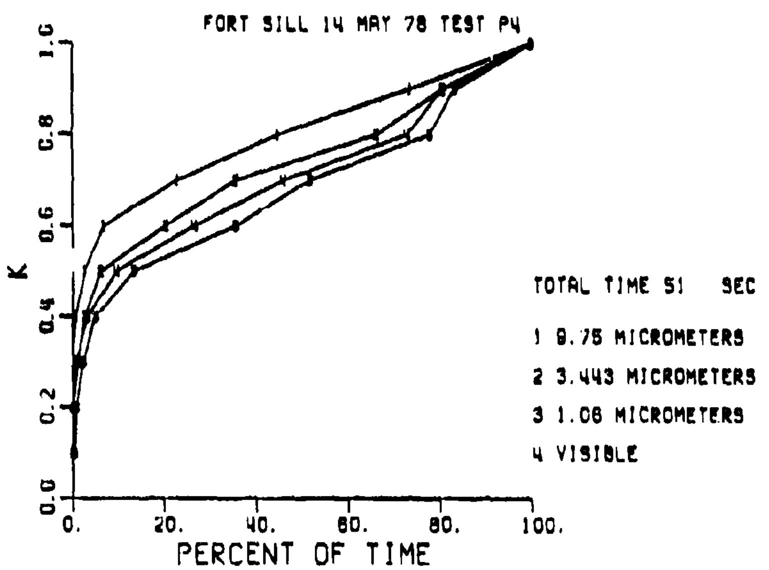

Figure 6. Percent of time measured transmittance was less than K, Fort Sill Test P4.

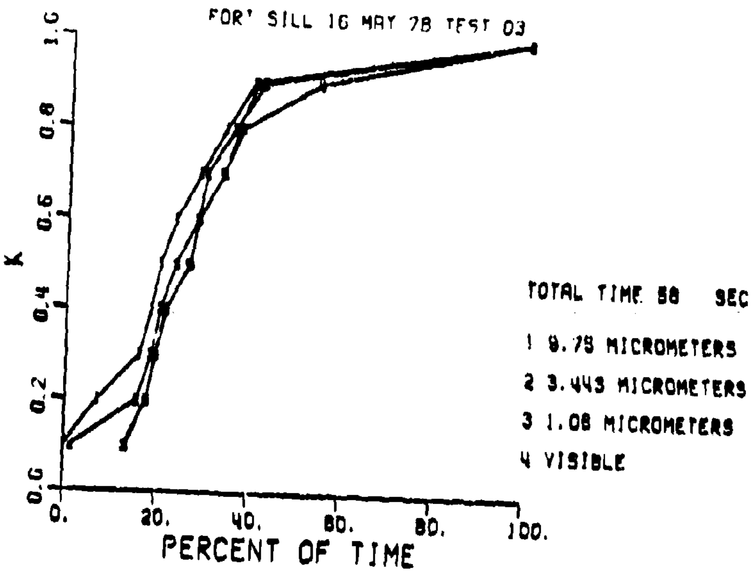

Figure 7. Percent of time measured transmittance was less than K, Fort Sill Test 03.

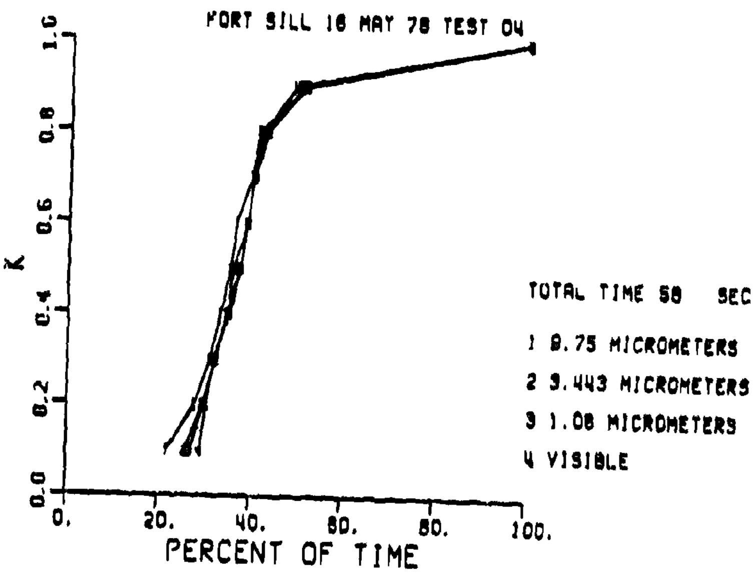

Figure 8. Percent of time measured transmittance was less than K, Fort Sill Test 04.

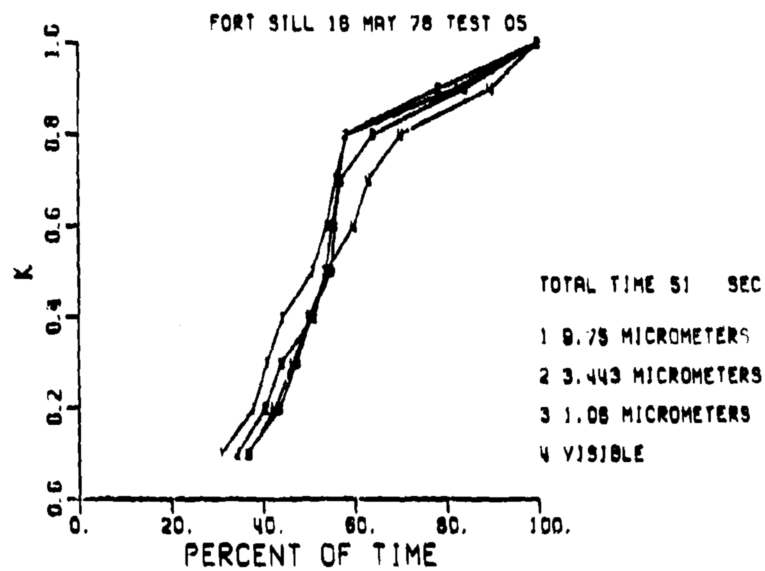

Figure 9. Percent of time measured transmittance was less than K, Fort Sill Test 05.

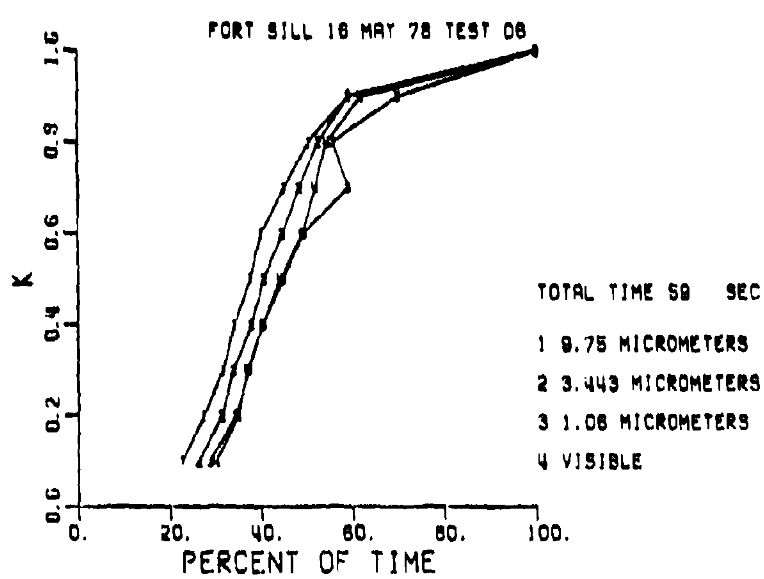

Figure 10. Percent of time measured transmittance was less than K, Fort Sill Test 06.

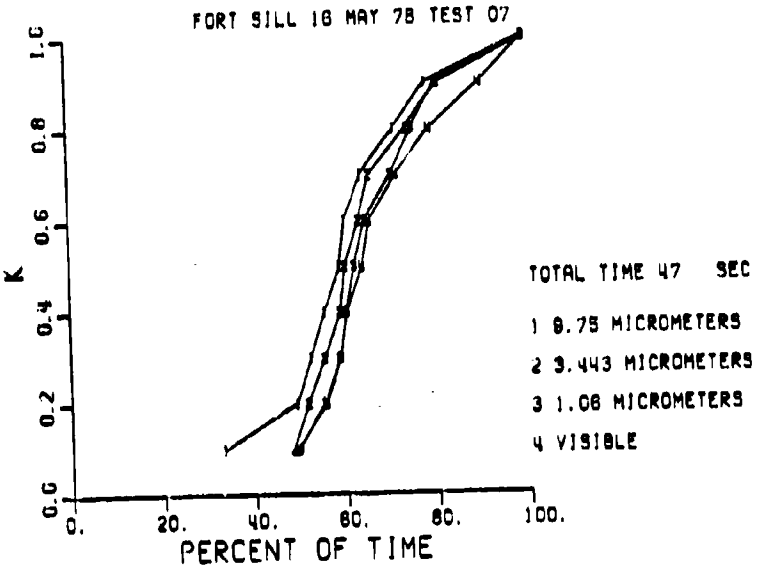

Figure 11. Percent of time measured transmittance was less than K, Fort Sill Test 07.

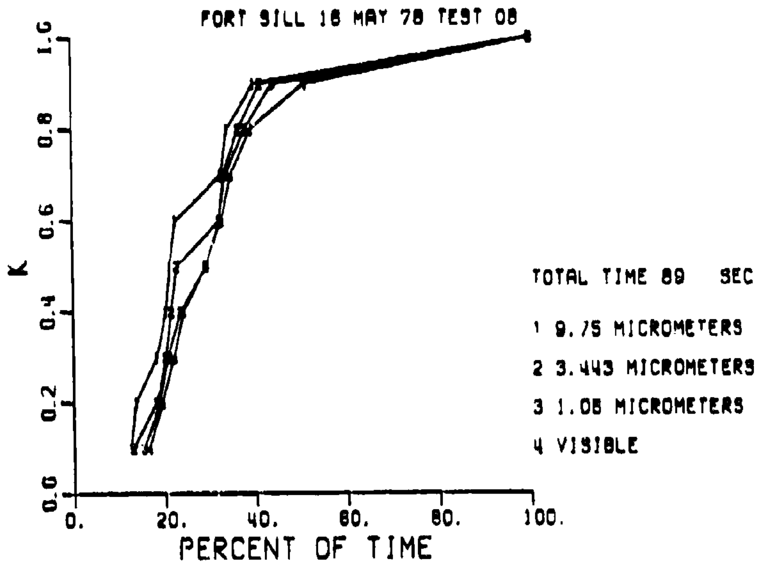

Figure 12. Percent of time measured transmittance was less than K, Fort Sill Test 08.

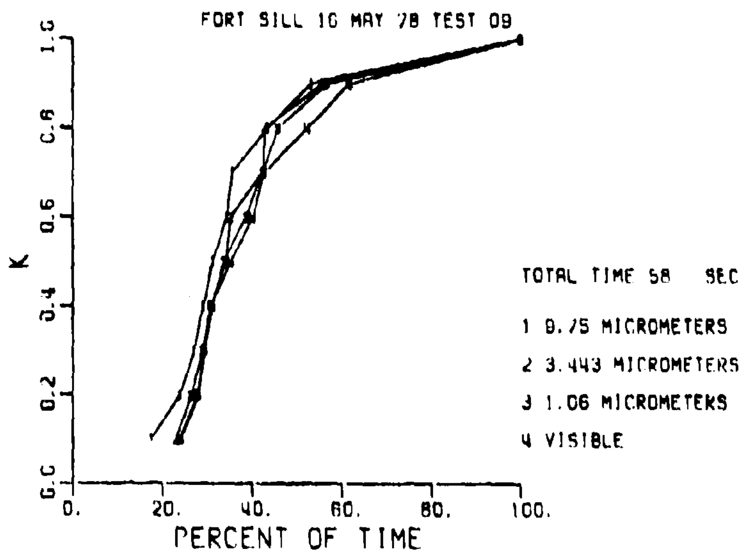

Figure 13. Percent of time measured transmittance was less than K, Fort Sill Test 09.

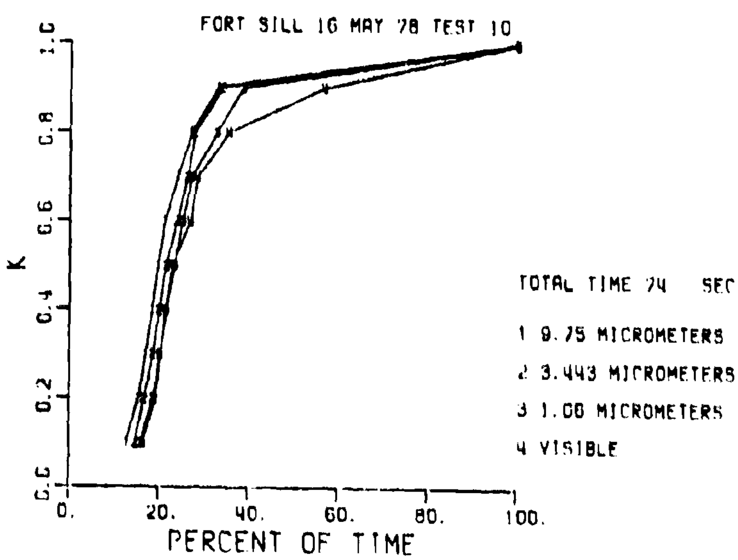

Figure 14. Percent of time measured transmittance was less than K, Fort Sill Test 10.

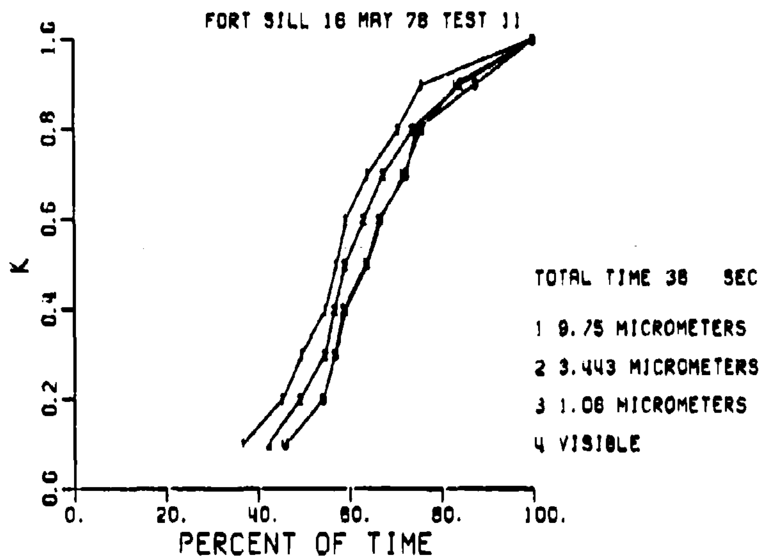

Figure 15. Percent of time measured transmittance was less than K, Fort Sill Test 11.

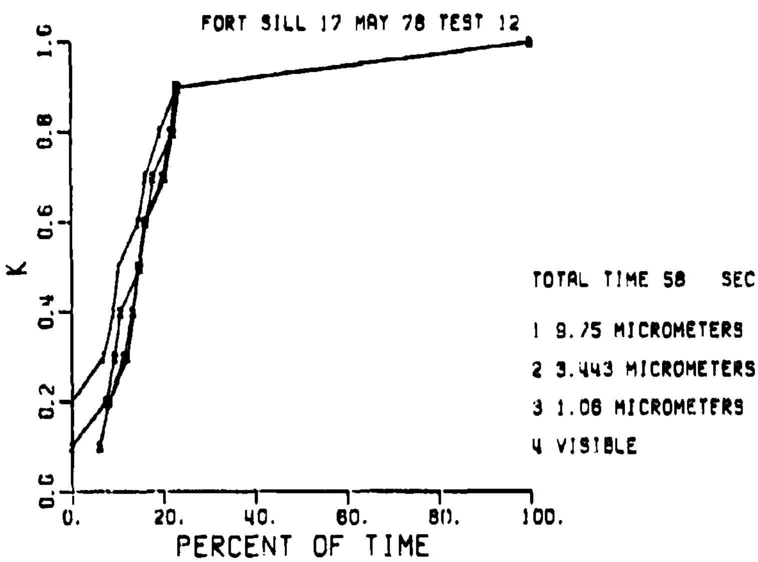

Figure 16. Percent of time measured transmittance was less than K, Fort Sill Test 12.

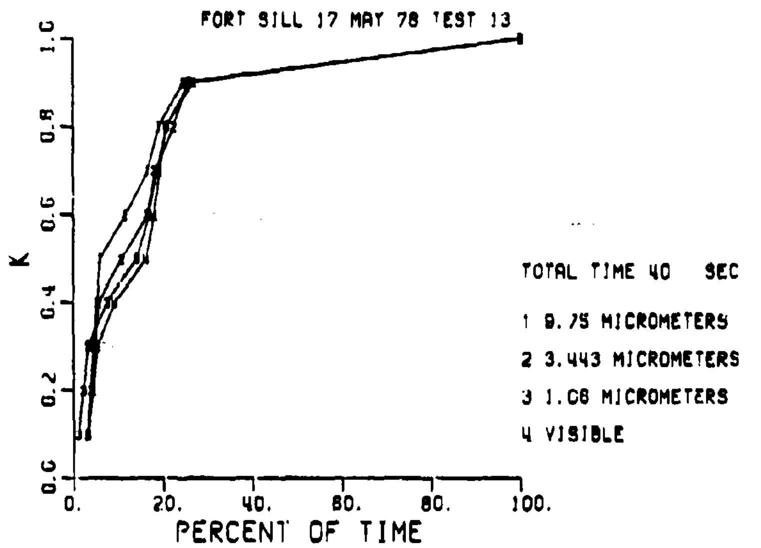

Figure 17. Percent of time measured transmittance was less than K, Fort Sill Test 13.

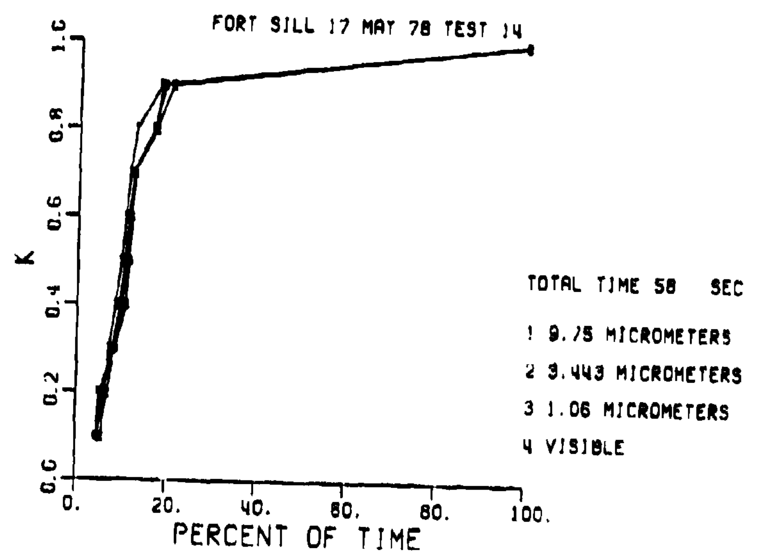

Figure 18. Percent of time measured transmittance was less than K, Fort Sill Test 14.

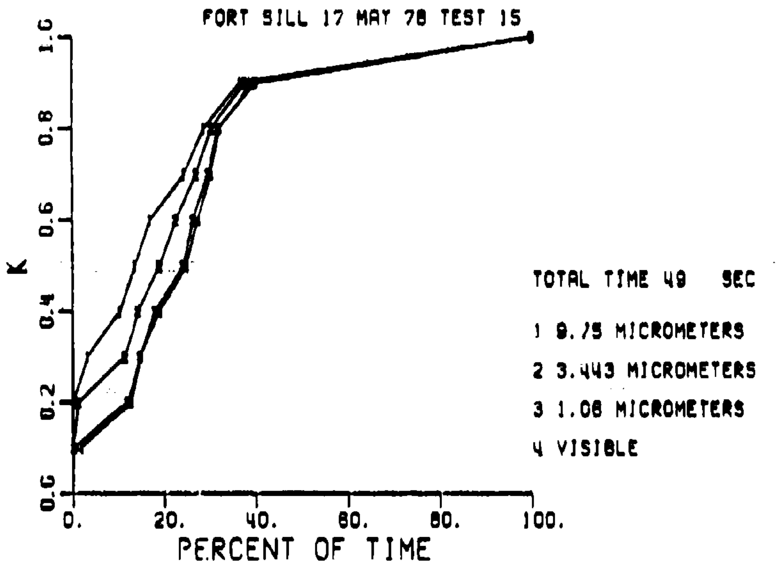

Figure 19. Percent of time measured transmittance was less than K, Fort Sill Test 15.

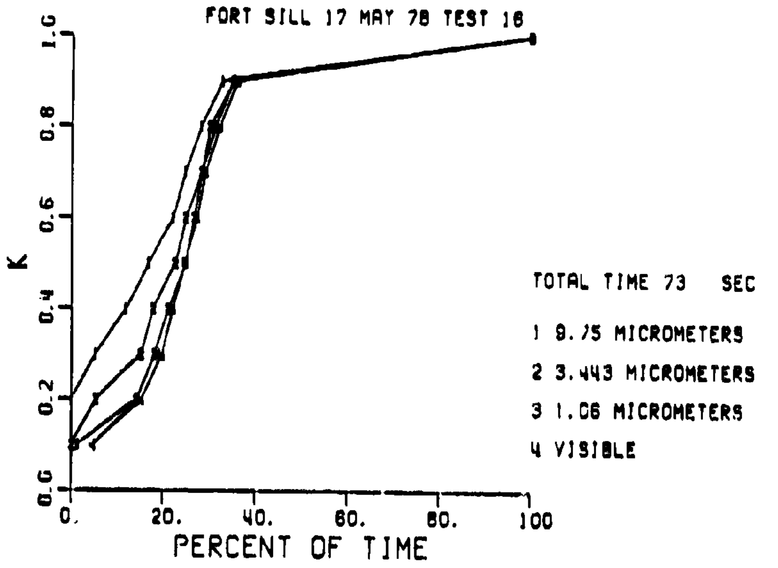

Figure 20. Percent of time measured transmittance was less than K, Fort Sill Test 16.

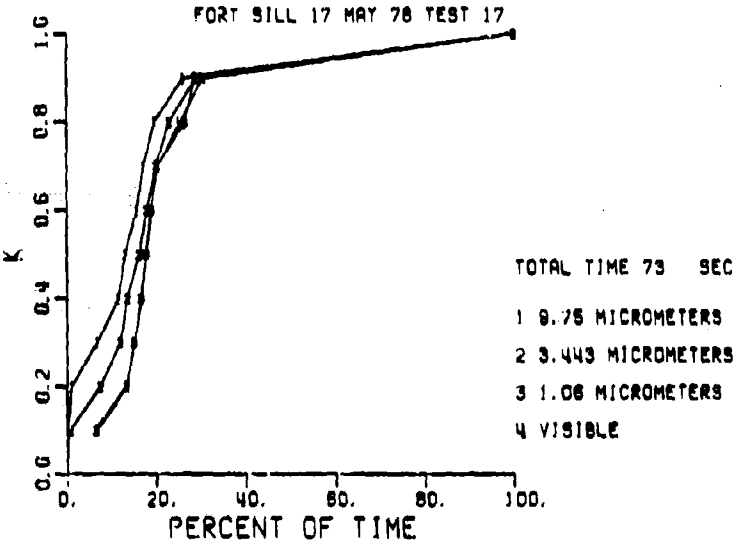

Figure 21. Percent of time measured transmittance was less than K, Fort Sill Test 17.

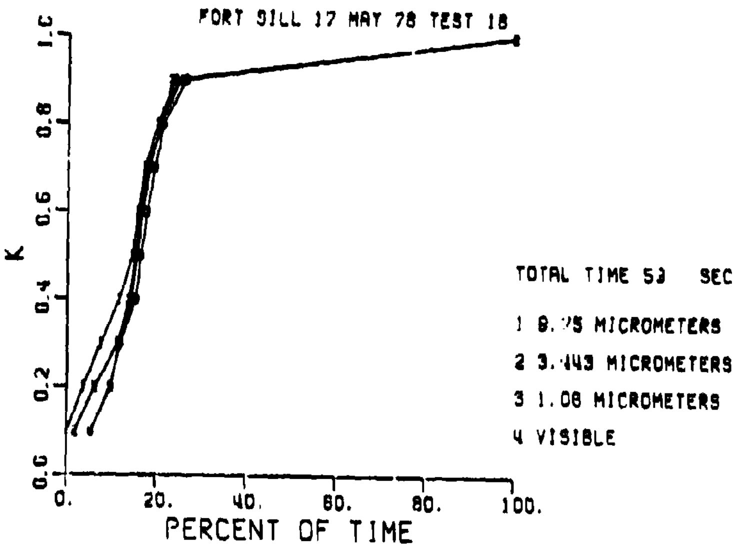

Figure 22. Percent of time measured transmittance was less than K, Fort Sill Test 18.

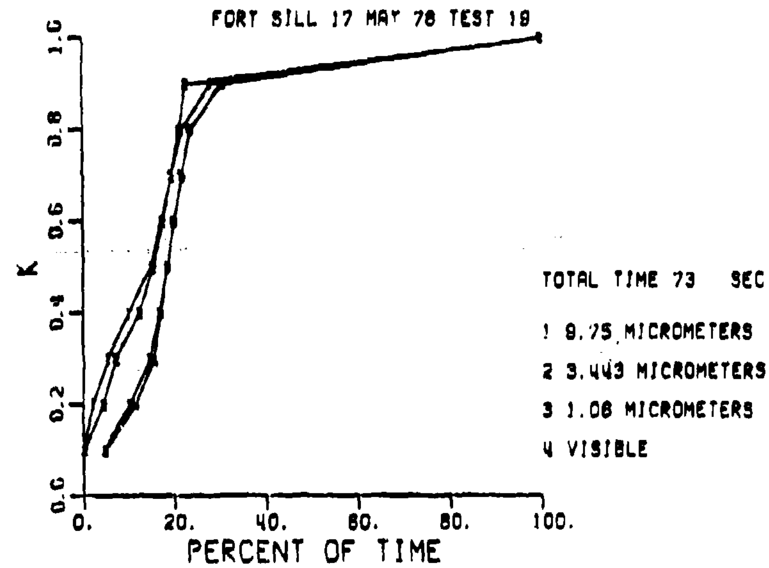

Figure 23. Percent of time measured transmittance was less than K, Fort Sill Test 19.

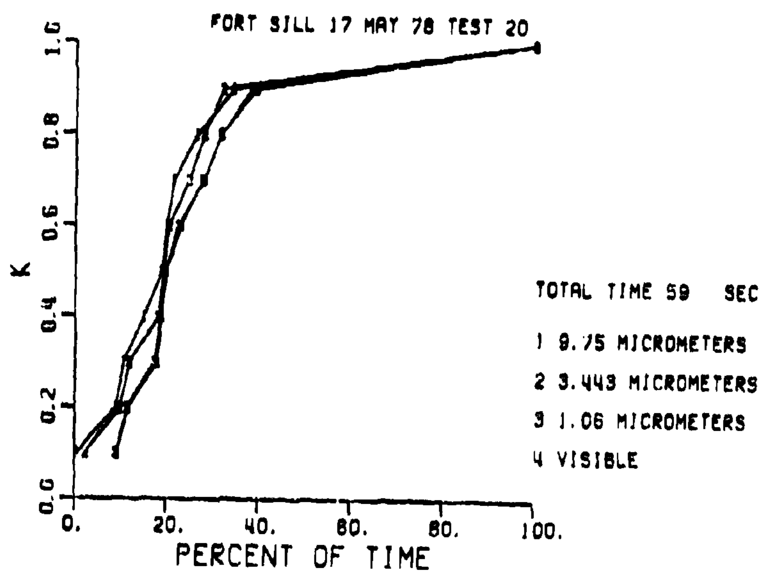

Figure 24. Percent of time measured transmittance was less than K, Fort Sill Test 20.

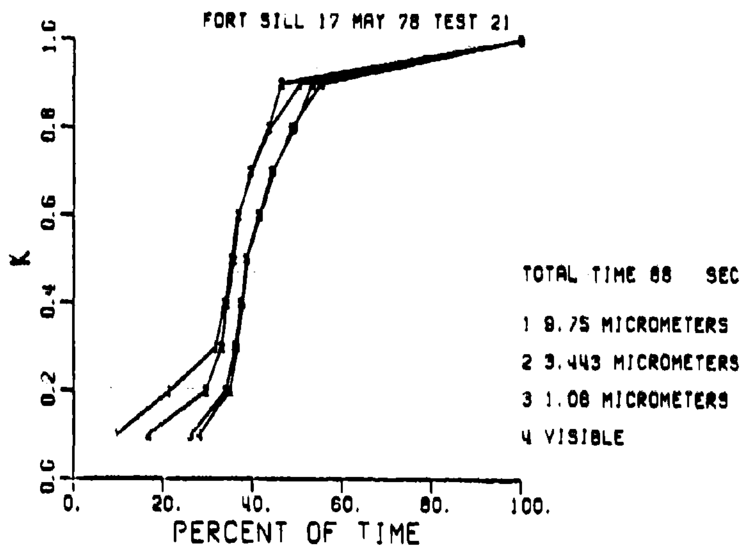

Figure 25. Percent of time measured transmittance was less than K, Fort Sill Test 21.

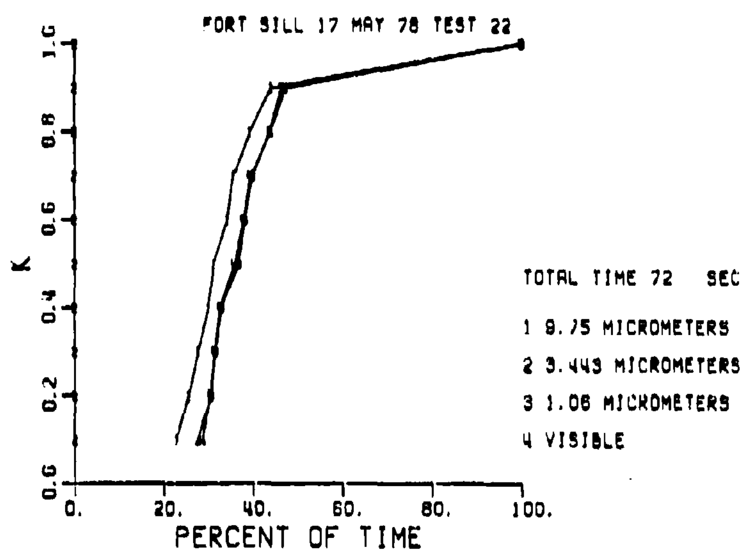

Figure 26. Percent of time measured transmittance was less than K, Fort Sill Test 22.

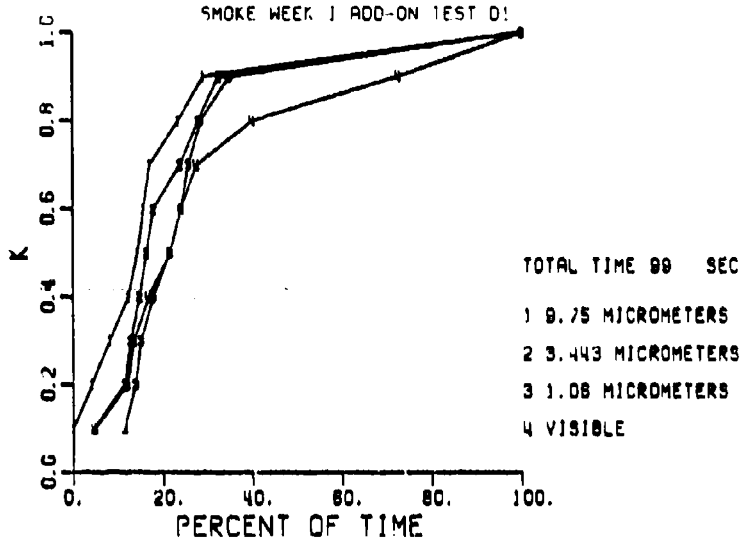

Figure 27. Percent of time measured transmittance was less than K, Smoke Week I Test D1.

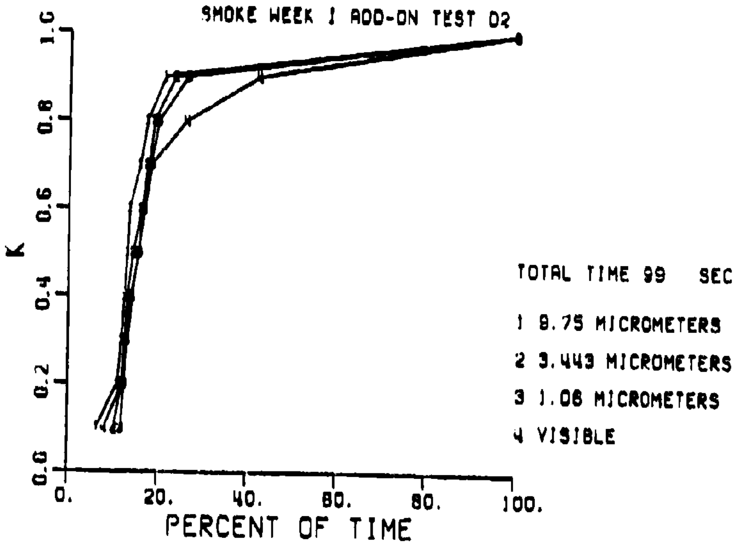

Figure 28. Percent of time measured transmittance was less than K, Smoke Week I Test D2.

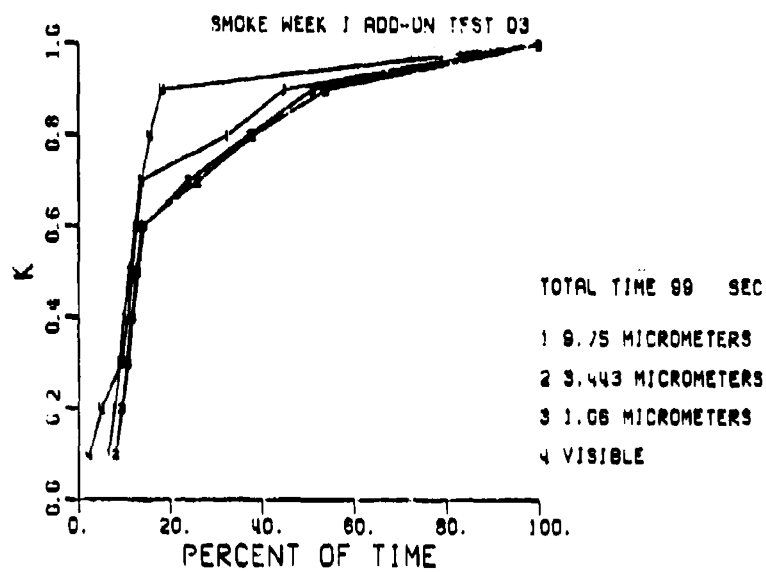

Figure 29. Percent of time measured transmittance was less than K, Smoke Week I Test D3.

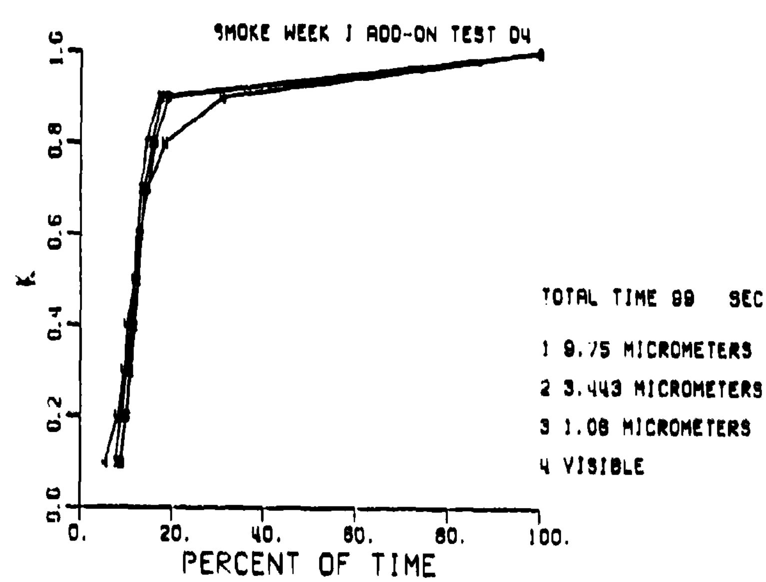

Figure 30. Percent of time measured transmittance was less than K, Smoke Week I Test D4.

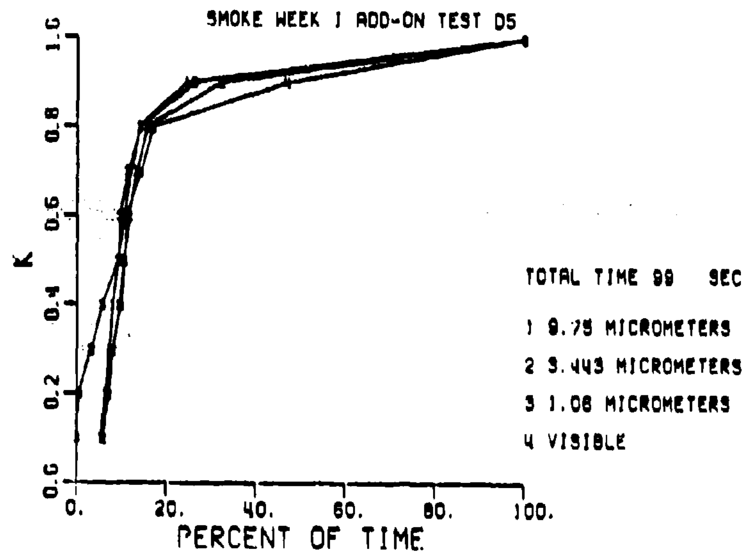

Figure 31. Percent of time measured transmittance was less than K, Smoke Week I Test D5.

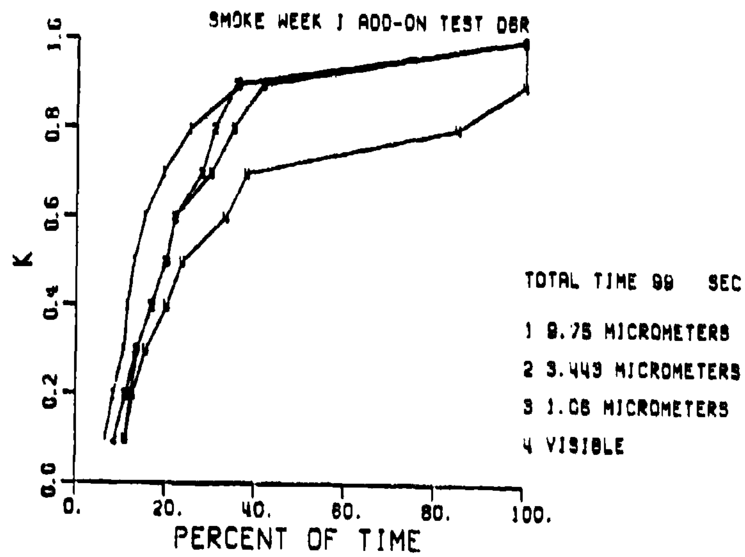

Figure 32. Percent of time measured transmittance was less than K, Smoke Week 1 Test D6R.

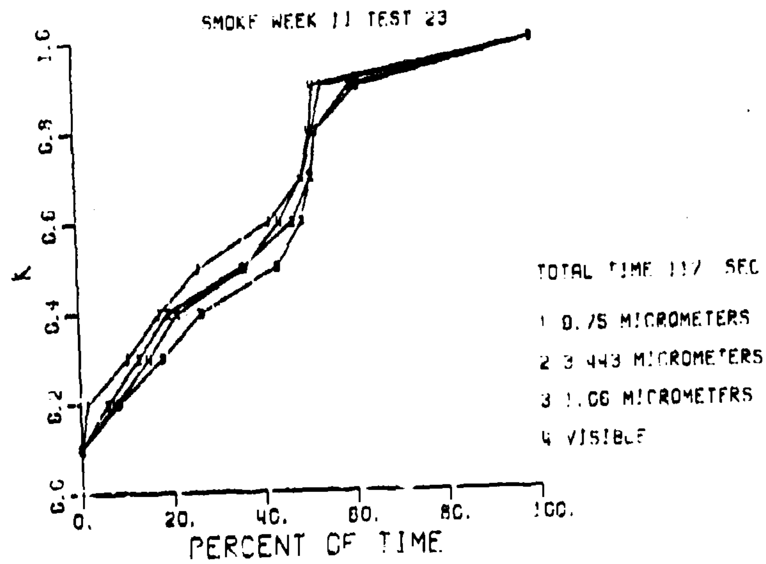

Figure 33. Percent of time measured transmittance was less than K, Smoke Week II Test 23.

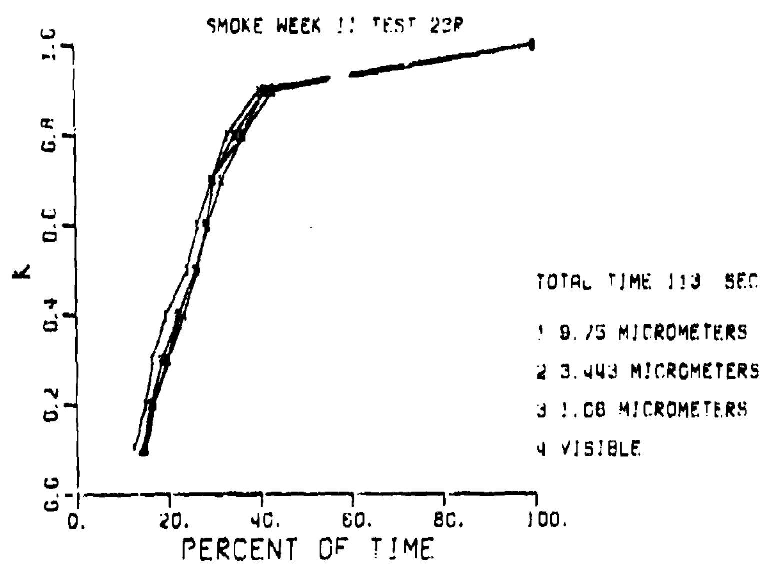

Figure 34. Percent of time measured transmittance was less than K, Smoke Week II Test 23R.

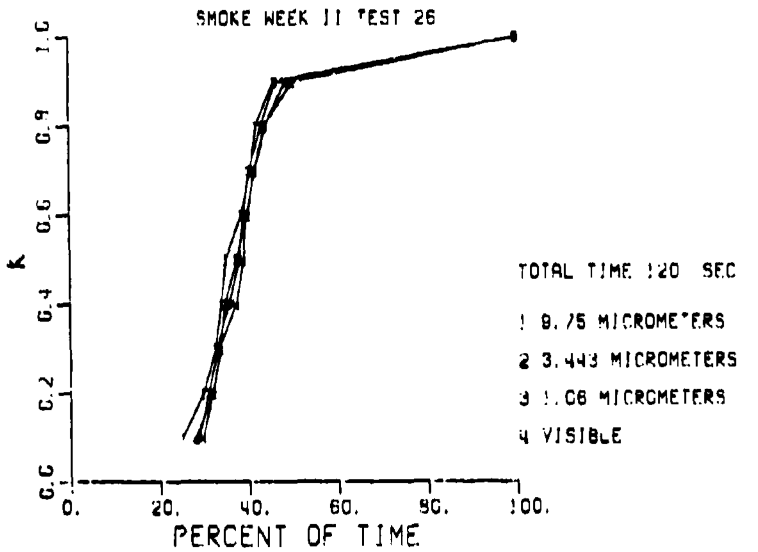

Figure 35. Percent of time measured transmittance was less than K, Smoke Week II Test 26.

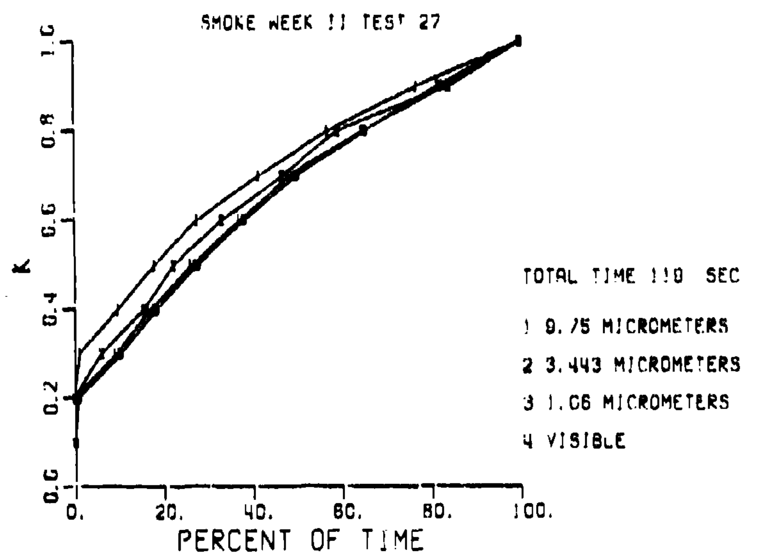

Figure 36. Percent of time measured transmittance was less than K, Smoke Week II Test 27.

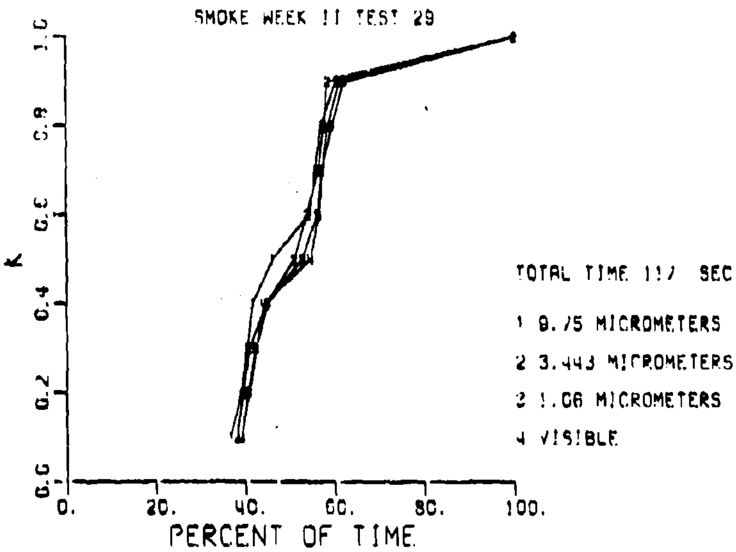

Figure 37. Percent of time measured transmittance was less than K, Smoke Week II Test 29.

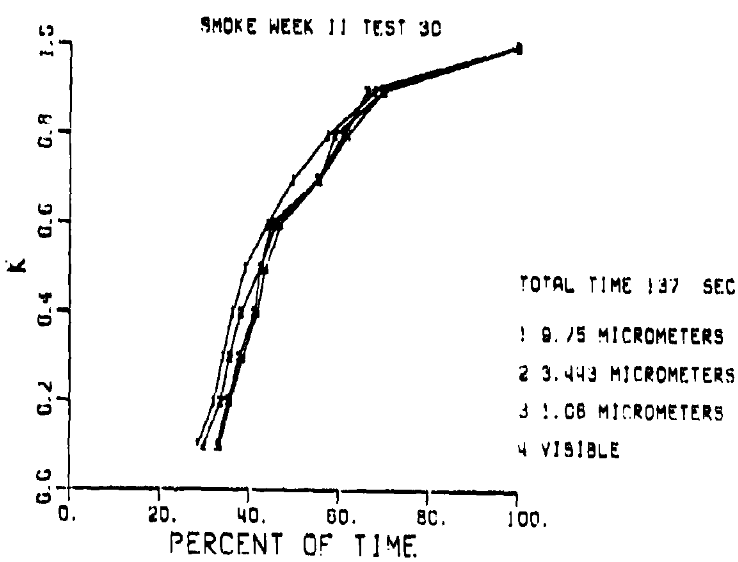

Figure 38. Percent of time measured transmittance was less than K, Smoke Week II Test 30.

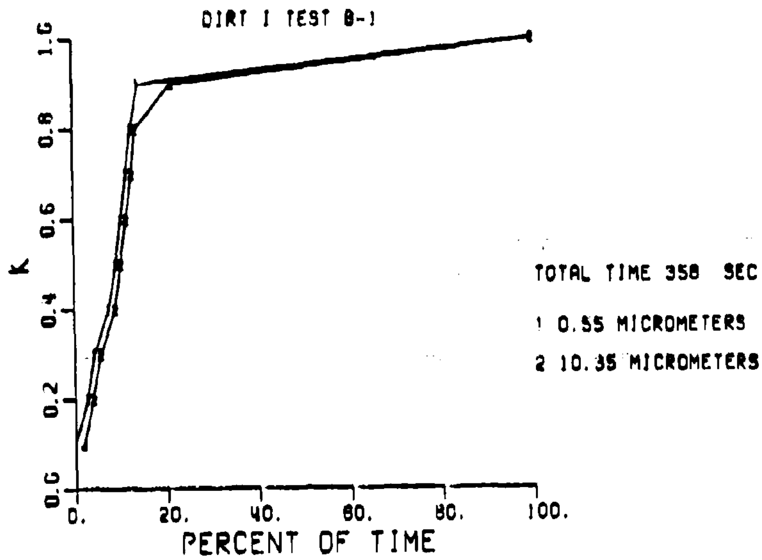

Figure 39. Percent of time measured transmittance was less than K, DIRT I Test B1.

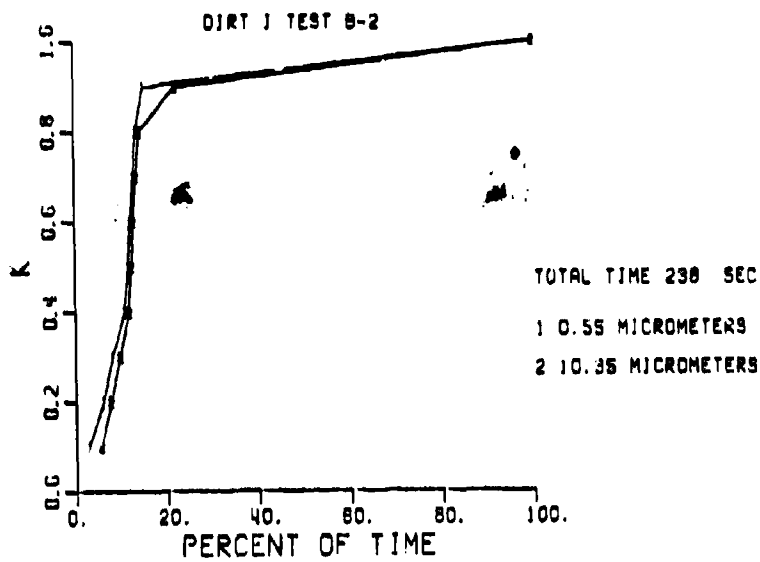

Figure 40. Percent of time measured transmittance was less than K, DIRT I Test B2.

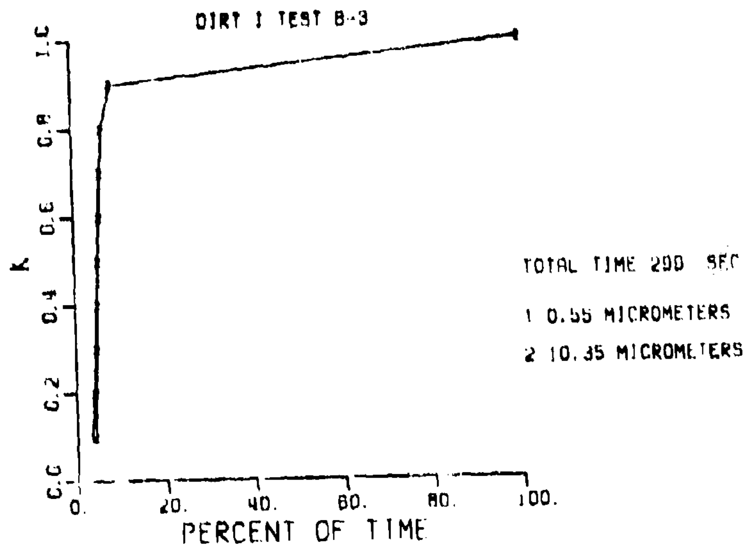

Figure 41. Percent of time measured transmittance was less than K, DIRT I Test B3.

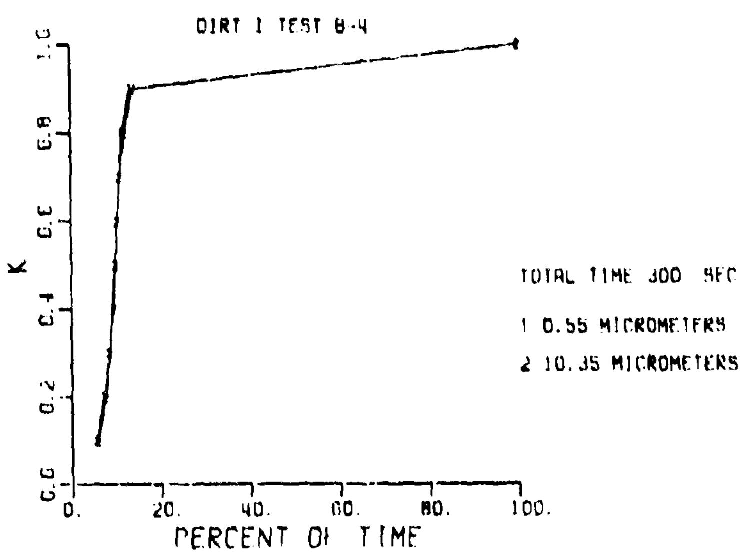

Figure 42. Percent of time measured transmittance was less than K, DIRT I Test B4.

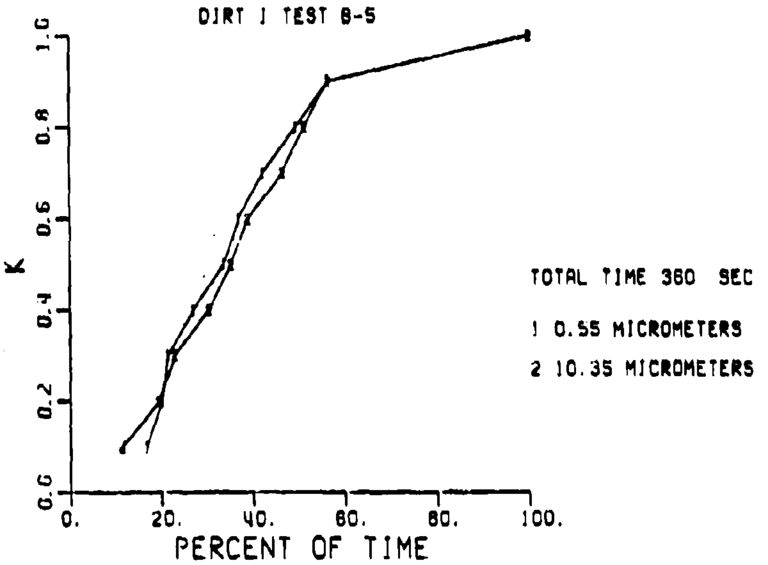

Figure 43. Percent of time measured transmittance was less than K, DIRT I Test B5.

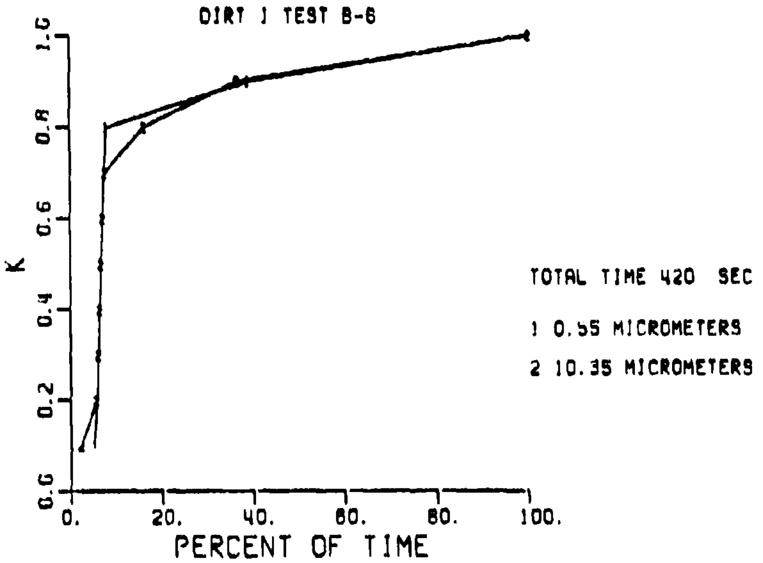

Figure 44. Percent of time measured transmittance was less than K, DIRT I Test B6.

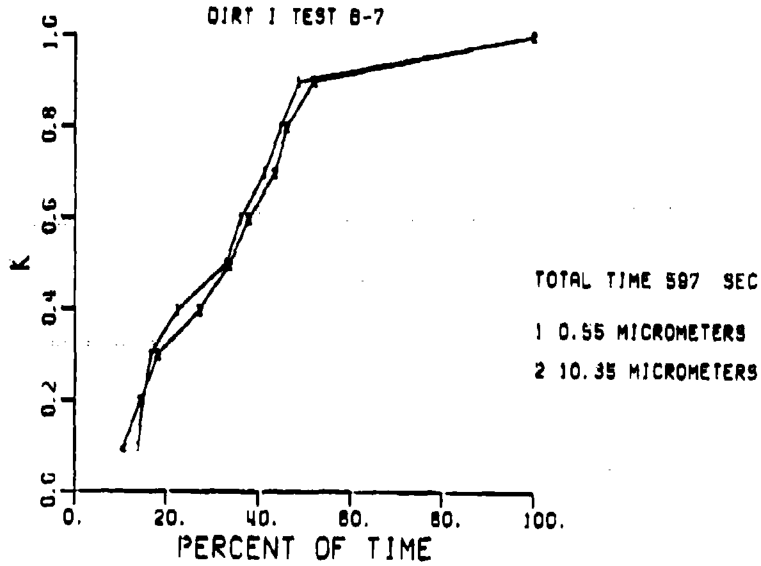

Figure 45. Percent of time measured transmittance was less than K, DIRT I Test B7.

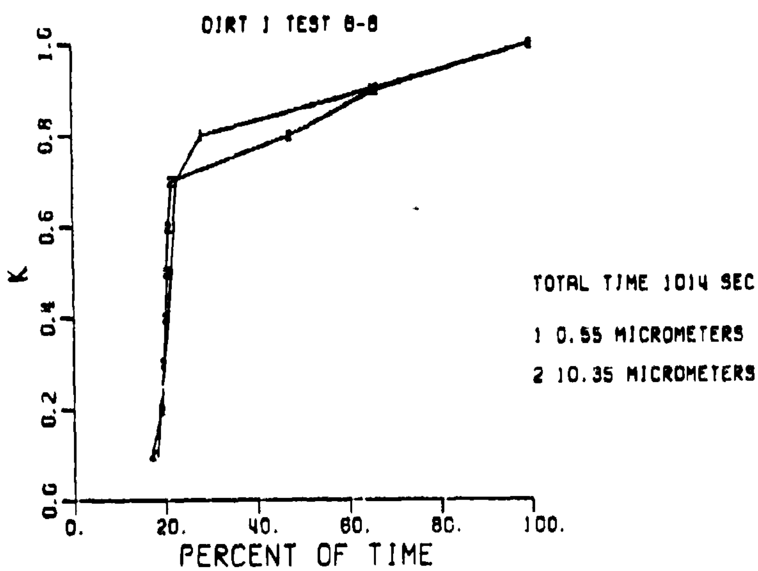

Figure 46. Percent of time measured transmittance was less than K, DIRT I Test B8.

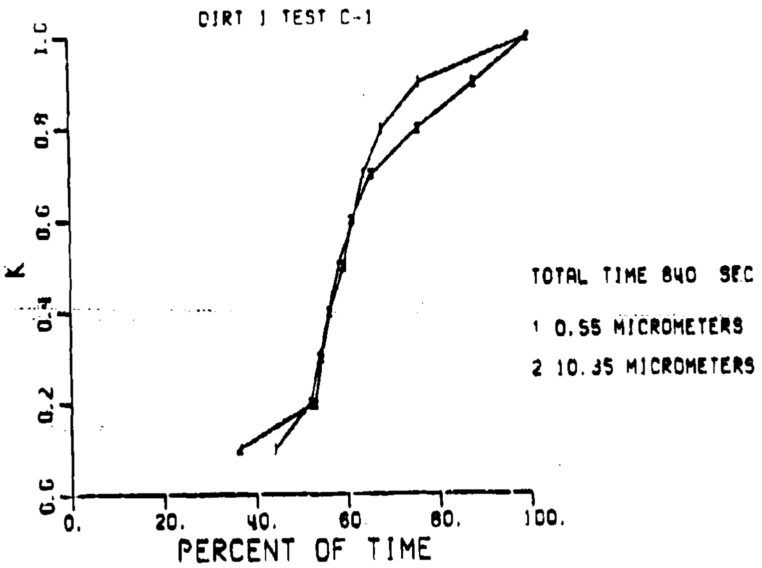

Figure 47. Percent of time measured transmittance was less than K, DIRT I Test C1.

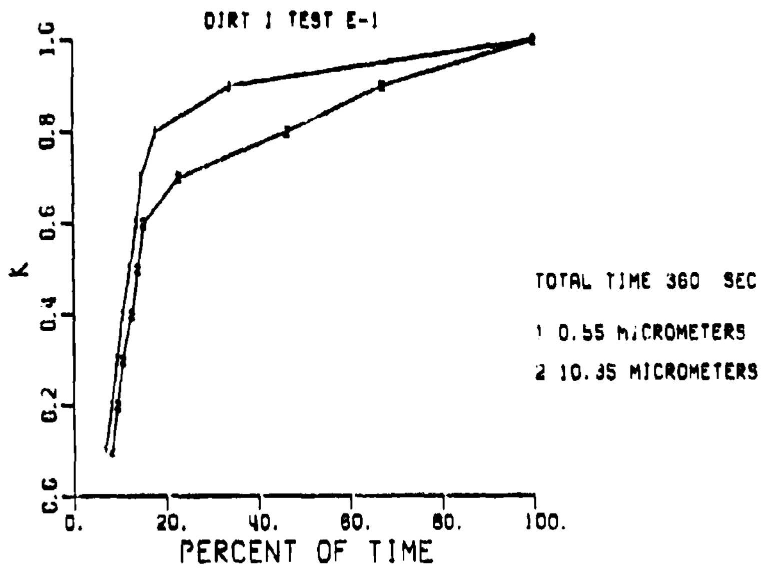

Figure 48. Percent of time measured transmittance was less than K, DIRT I Test E1.

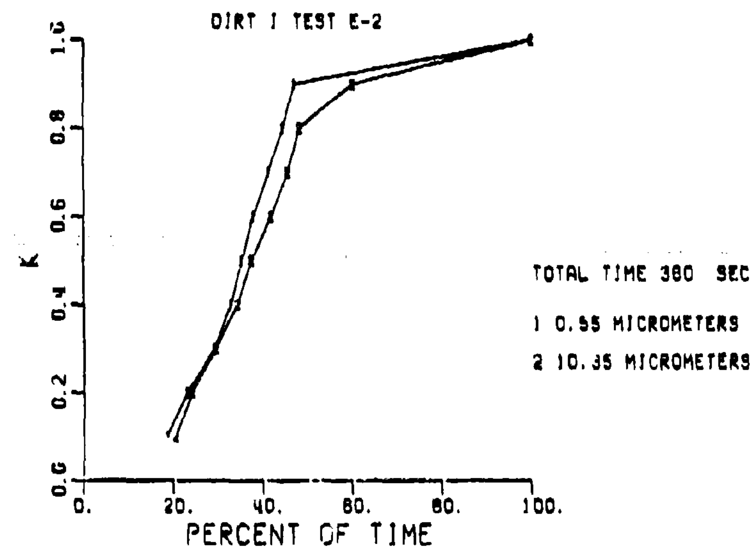

Figure 49. Percent of time measured transmittance was less than K, DIRT I Test E2.

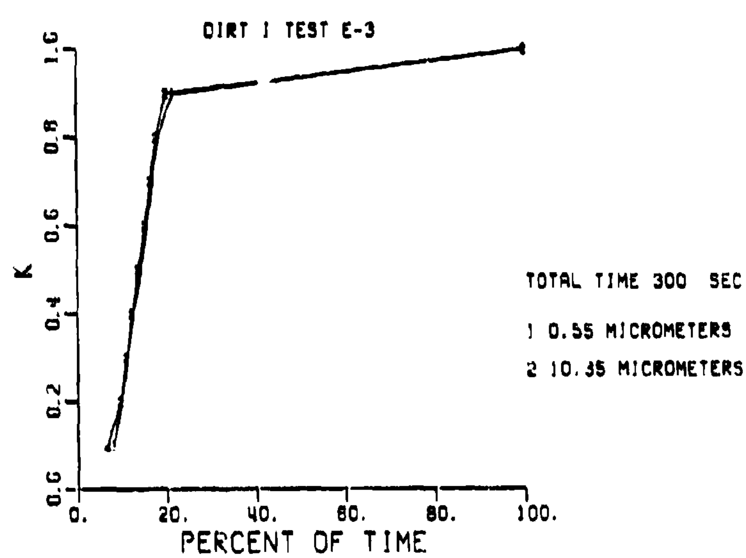

Figure 50. Percent of time measured transmittance was less than K, DIRT I Test E3.

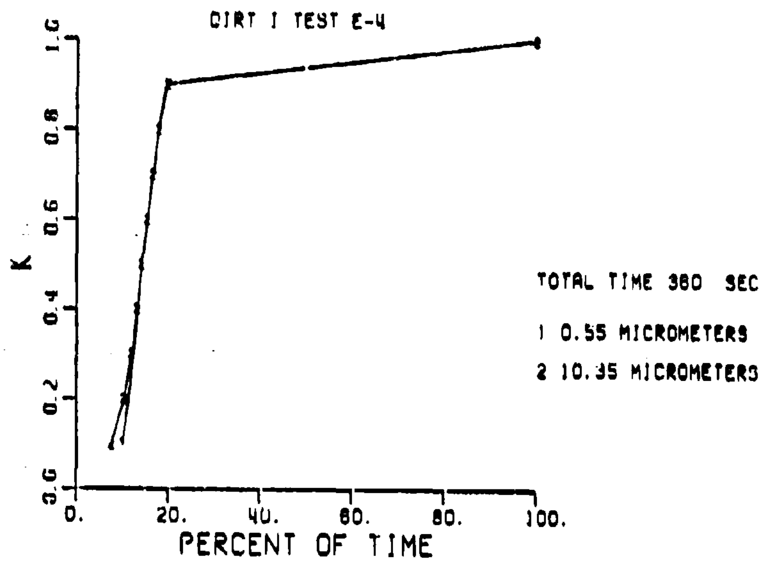

Figure 51. Percent of time measured transmittance was less than K, DIRT I Test E4.

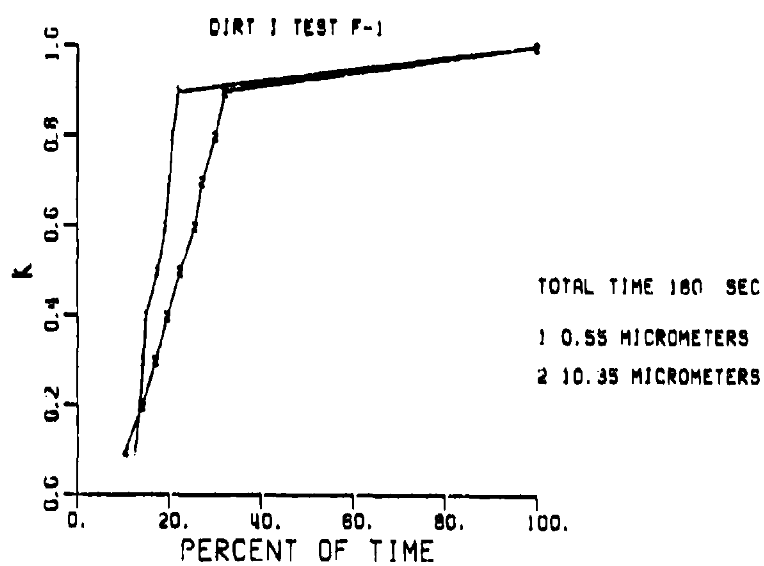

Figure 52. Percent of time measured transmittance was less than K, DIRT I Test F1.

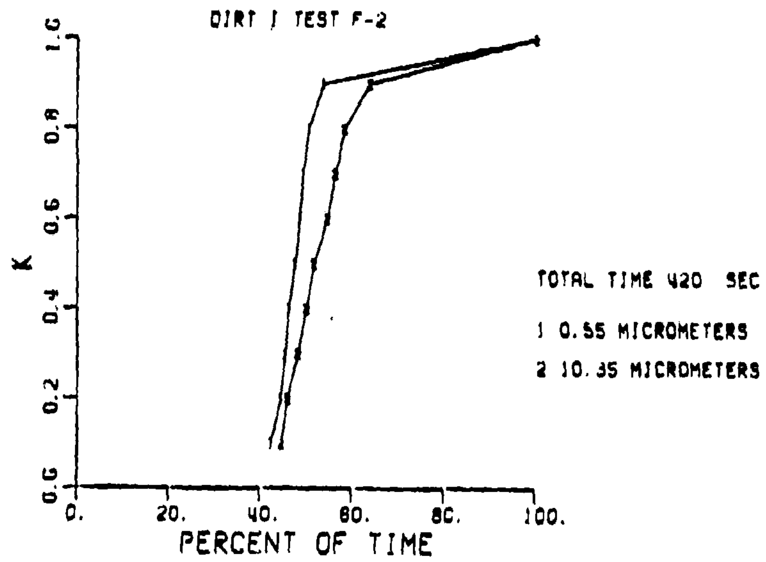

Figure 53. Percent of time measured transmittance was less than K, DIRT I Test F2.

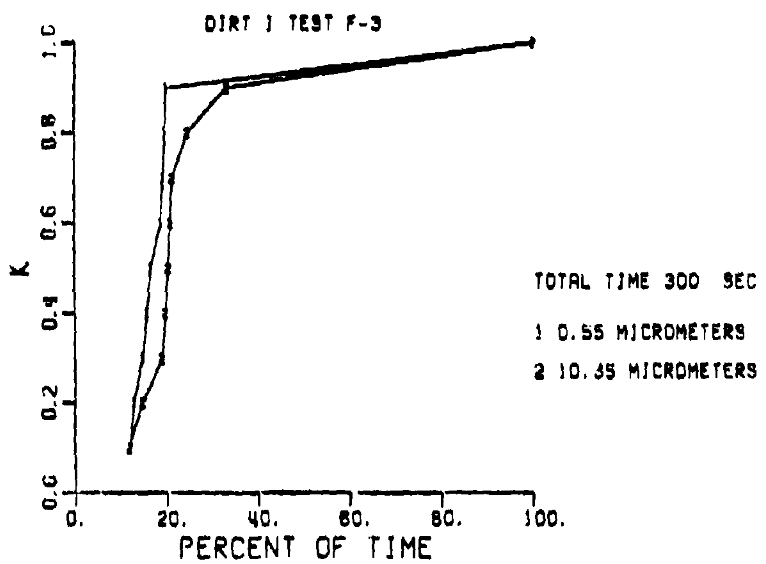

Figure 54. Percent of time measured transmittance was less than K, DIRT I Test F3.

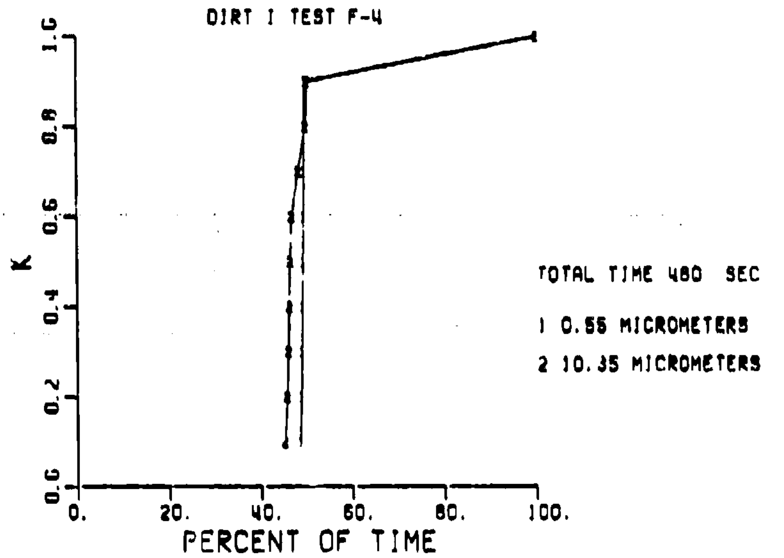

Figure 55. Percent of time measured transmittance was less than K, DIRT I Test F4.

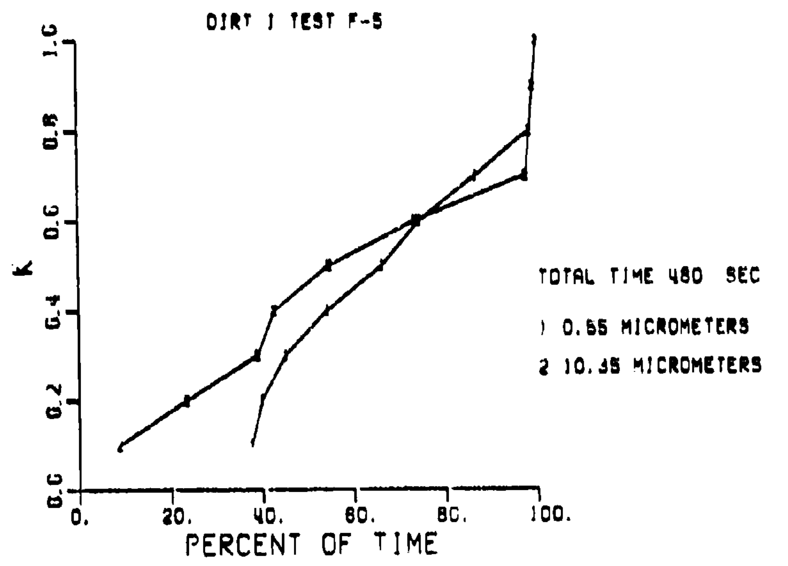

Figure 56. Percent of time measured transmittance was less than K, DIRT I Test F5.

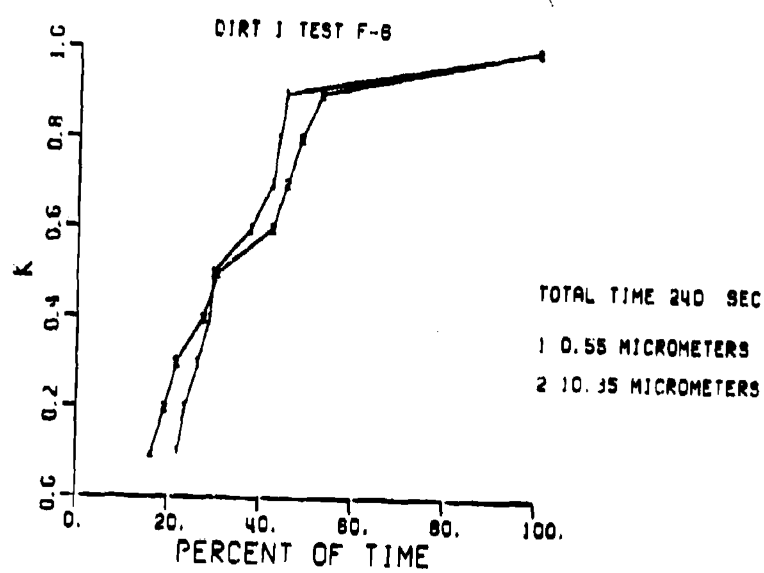

Figure 57. Percent of time measured transmittance was less than K, DIRT I Test F6.

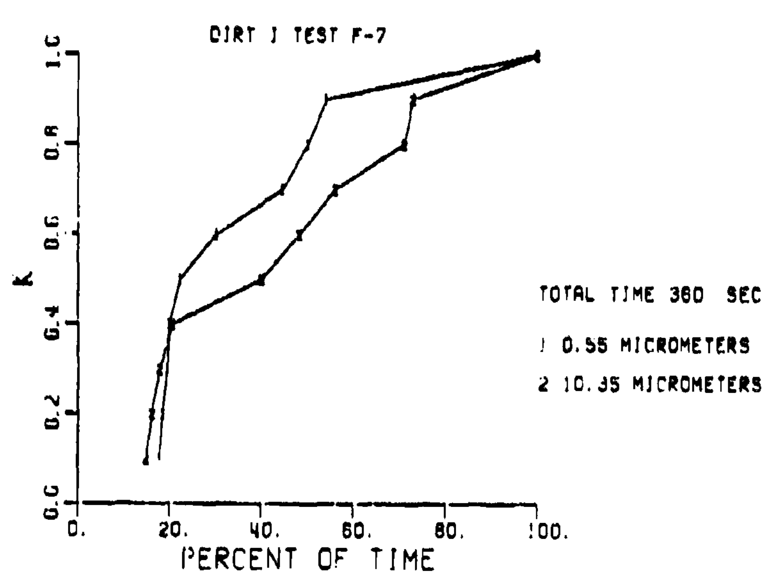

Figure 58. Percent of time measured transmittance was less than K, DIRT I Test F7.

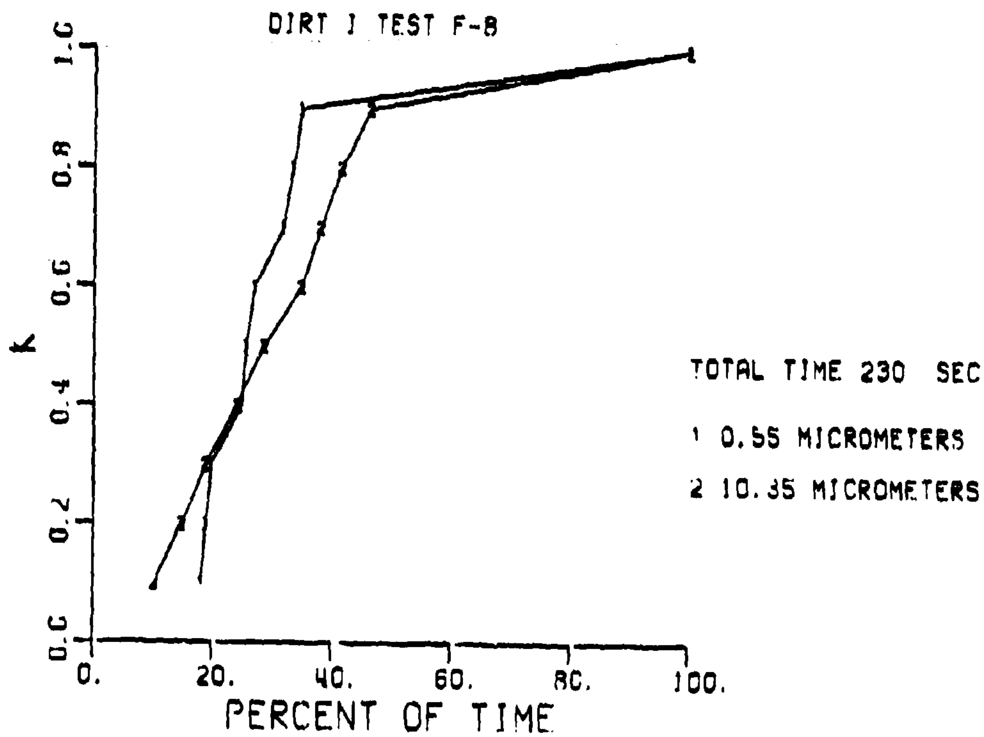

Figure 59. Percent of time measured transmittance was less than K, DIRT I Test F8.

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